Colorado Native Pollinating Insects Health Study

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Cover: The illustration shows the diversity of pollinator insects and land-management actions that can help pollinator conservation across many landscapes. Artwork by Faith Williams Dyrsten.

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Inquiries about this study should be directed to the Colorado Department of Natural Resources

Contents

Photo: Christian Nunes

Executive Summary

Introduction

Colorado is home to an incredibly rich community of native pollinating insects that contribute to the state's economy and enhance Coloradans' quality of life through the irreplaceable role they play in ecosystems. The pollination services these essential insects provide are at the heart of a healthy environment, contributing to our agricultural production and food systems, and relied upon by flowering plants across the state. In turn, flowering plants support the state's wildlife, add color to the beautiful landscapes that we all treasure, and provide the basis for healthy functioning ecosystems.

Despite their central importance, however, to date, no comprehensive assessment of the health of the state's native pollinating insects has been conducted. Recognizing this need for coordinated state-level efforts to better understand the status and health of our native pollinating insects, Senate Bill 22-199, the Native Pollinating Insects Protection Study, was passed by the State Legislature and signed into law by Governor Jared Polis in May 2022. The Colorado Department of Natural Resources subsequently commissioned this study, awarded to a collaborative team of pollinator researchers, managers, and conservationists. The study was

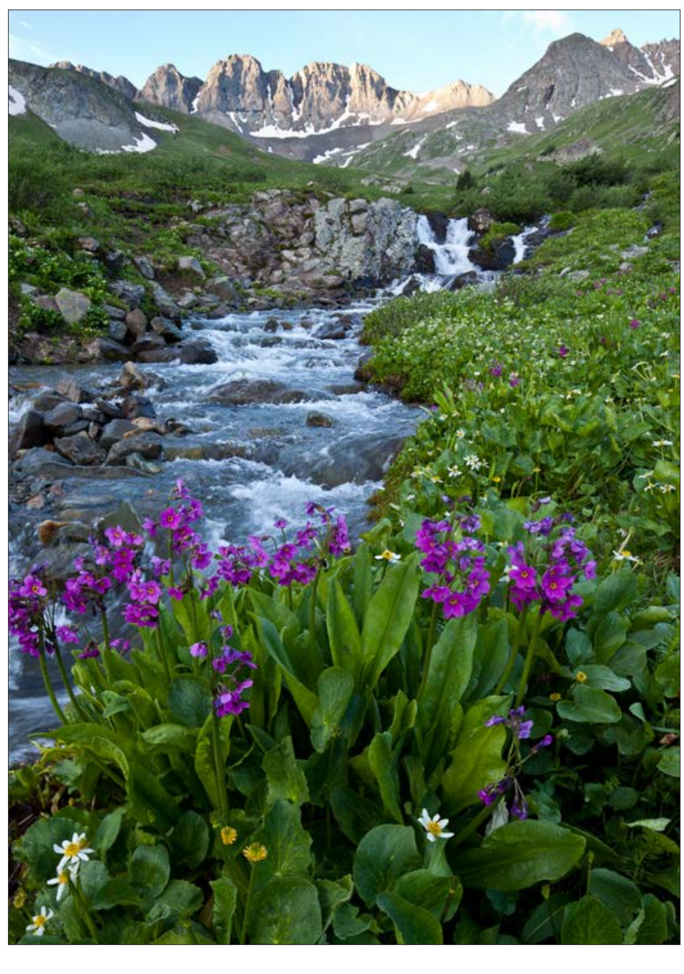


Figure 1. Declining pollinators like the golden-belted bumble bee (*Bombus balteatus*) (below) are crucial for the health of Colorado's iconic landscapes, where they pollinate many plants, including the colorful Parry's primrose (*Primula parryi*), pictured here (right) growing along a stream near Handies Peak. (Photos: [bumble bee] Arnstein Staverløkk / Norsk institutt for naturforskning; [primrose] Bob Wick, BLM.)

coordinated by Colorado State University Extension, in collaboration with the Xerces Society for Invertebrate Conservation and the University of Colorado Museum of Natural History, and in cooperation with leading experts in native pollinating insect ecology, management, and conservation.

The goals of this study are to explore the status of native pollinating insects within the state and develop recommended land management practices for their management and conservation. The study focuses on statewide management and conservation of native pollinating insects on lands owned and managed by the state. Therefore, the intended audiences of this study are state agencies, land managers within those agencies, and policymakers, all of whom could take action based upon the recommendations of this study. This document is also relevant to tribal and local governments, conservation organizations, educational institutions, researchers and scientists, farmers and agricultural communities, and the general public.

Following the **Introduction (Section 1)**, this report is divided into three major sections. A brief description of each follows below:

- **Scientific Review (Section 2)**: A synthesis of the research providing evidence for the importance of native pollinating insects to agricultural and natural resources within the state and key factors impacting the diversity and health of native pollinating insects.
- **Conservation Practices (Section 3)**: This outlines 1) general considerations for incorporating pollinating insects into conservation practices and management programs, 2) existing state efforts focused on native pollinators, and 3) how to apply concepts from the scientific understanding to the needs and management of pollinating insects.
- **Future Priorities (Section 4)**: The potential outcomes from this report, including suggested priorities for Colorado native pollinating insect health, ways to foster more collaborative conservation and management practices, and potential resources necessary for the state to act upon these recommendations.

Scientific Review of Colorado Native Pollinating Insects

Colorado is home to just over 1,000 species of bees—nearly 30% of North America's and approximately 5% of the world's bee species—and nearly 300 species of butterflies, over 40% of the diversity of butterflies in North America north of Mexico. It is also home to many other species of insects that are much less well-known but also play a vital role in pollinating flowers. Some of these species are already imperiled. Three species of Colorado butterflies are currently federally protected under the Endangered Species Act, and five bumble bee species, over a fifth of the species within the state, are petitioned or under review for ESA listing by the US Fish and Wildlife Service. While these numbers may sound alarming, they are likely a huge underestimate of the true scope of imperiled pollinator species within the state, as many groups have been little studied and many species are rare, feed on only a handful of plants or flowers, or have extremely restricted distributions within the state. Therefore, evidence of declines in some species is likely indicative of systemic threats to native pollinating insects across the state.

The primary drivers of declines of native pollinating insects in Colorado are:

- Habitat loss from the permanent conversion of natural areas to agriculture or development is the biggest threat, as most crops and urban habitats provide few resources for native pollinating insects. However, evidence suggests that diversifying crops or creating habitats within agricultural and

urban landscapes can promote more diverse and healthy native pollinating insects—and connecting habitats across landscapes can further help mitigate impacts from habitat loss.
- Some land management practices associated with grazing and forestry also harm pollinators, although a growing body of evidence shows that considering pollinators while planning and implementing management can help mitigate those impacts, and some forestry and grazing practices can be valuable conservation tools.
- Pesticides, including insecticides, herbicides, and fungicides, are significant drivers of pollinating insect decline in agricultural and urban landscapes and reducing pesticide use can help minimize their impacts on pollinators.
- Non-native species of plants and insects, including managed pollinators like honey bees, can have negative impacts on native pollinating insects, and should be considered in the conservation of native pollinators.
- Climate change negatively impacts pollinators and the plants they depend on, and these impacts will play an increasingly important role in the future. Although climate-change impacts are well studied, how best to mitigate those impacts is a major gap for both conservation and management.

Thus, the status of Colorado's native pollinating insects is tenuous. While Colorado's landscapes are diverse, the factors that negatively impact native pollinators are similar. Those impacts are strongest in agricultural and urban habitats, but even within protected habitats human-caused environmental change is negatively impacting pollinators. However, replacing harmful human practices and adopting practices to promote pollinating insects—especially in agricultural and urban habitats—represents the biggest opportunity to foster healthy native pollinating insects.

Conservation Practices for Pollinating Insects & Their Habitats

Each species of Colorado's native pollinating insects is unique in how and when it reproduces, what it feeds upon, the habitat in which it lives, and where in the state it is found. Prescribing conservation practice recommendations that are ideal for all pollinators in all places across Colorado is impossible: there is no one-size-fits-all solution.

Figure 2. Leonard's Pawnee skipper (*Hesperia leonardus pawnee*) getting warmed by the sun on a blue grama (*Bouteloua gracillis*) seed head. (Photo: Christian Nunes.)

Successful management for pollinators should ideally be implemented based on the species, specific sites and habitats, and management goals of these areas. However, there are a suite of general considerations (see Table 1) that can benefit pollinators in most situations and which are scalable to a state park, wildlife area, roadway, or even to a landscaped area around a building. These broad factors apply to most land-management situations and provide a framework to guide and shape conservation of pollinator communities in almost any situation.

Table 1. General pollinator conservation and management practices

Conservation Practices	Management Practices
• Identify and protect existing pollinator habitat • Create and connect habitats, provide refuges • Address invasive plants and insects through integrated pest management • Avoid or minimize the use of pesticides • Adaptively manage • Factor managed pollinators (European honey bee) into conservation considerations • Consider how management interacts with natural stressors to affect pollinators (e.g., climate change, drought, extreme weather, wildfires) • Time management activities to minimize negative impacts on pollinators	• Conservation on Agricultural Crop Lands • Mowing and Haying • Forests and Shrublands • Grazing and Rangelands • Integrated Pest Management and Pesticide Risk Reduction • Integrated Weed Management and Herbicides • Restoring and Creating Pollinator Habitat • Prescribed Fire Management

Table 2. Existing and recommended state agency programs and policies.

<table>
<tr><th>Conservation Practices</th><th>State Agency Policy and Program Recommendations (continued)</th></tr>
<tr><td>• I-76 Colorado Pollinator Highway Project (CDOT).
• Landscaping Requirements and Colorado Pollinator Highways Procedural Directive #503.1 (CDOT).
• Pollinator Conservation Policy Administrative Order DNR-108 (DNR).
• Colorado State Wildlife Action Plan (SWAP) (DNR & CPW).
• State Natural Areas Program (DNR & CPW).
• Stewardship Action Plans (DNR & SLB).
• Greening Government Executive Orders D2023 018 and D2022 016.</td><td rowspan="3">and all invertebrates as wildlife (DNR).
• Evaluate the potential funding needs associated with implementing recommended policies, programs, new staff positions, and other actions needed to improve state efforts to conserve pollinators (DNR).
• Add pollinator-related staff positions to support improved coordination and support for pollinator conservation and habitat improvements (CPW & CDOT).
• Evaluate and implement pollinator and pollinator habitat monitoring and survey programs (CPW).
• Create a Pollinator Stewardship Action Plan (SAP) (SLB).
• Assess managed honey bee (apiary) registration, license, or inspection programs occurring in other states to determine potential models that would be sustainable for the state to adopt and implement (CDA).
• Integrate pollinator conservation practices into the content and standards for pesticide applicator license requirements.
• Establish a statewide policy or directive to prioritize the use of native plants</td></tr>
<tr><th>State Agency Policy and Program Recommendations</th></tr>
<tr><td>• Increase the extent of pollinator habitat along the Colorado Pollinator Highway and increase the number of other roadway pollinator habitat projects (CDOT).
• Collaboration between state agencies that purchase native seeds and plants to align and leverage the State’s purchasing influence to improve the supply of native plant materials.
• Evaluate and pursue statutory authority for the management of bees, butterflies, other pollinators,</td></tr>
</table>

Management practices that occur on state lands have the potential to negatively impact pollinators and their habitats. When pollinator-friendly approaches are taken, risks can be mitigated or conditions for pollinators improved. Several state agencies implement some of these practices in ways that align with pollinator conservation and such practices should be encouraged and amplified. Common barriers that impede more frequent use of recommended practices, such as a lack of agency policy, lack of training, or lack of staffing, are good targets for making improvements.

Several state agencies have current programs and policies related to conserving pollinators and their habitats that are important to continue and, where feasible, expand their reach (see Table 2). While some of these programs and policies might not directly call out pollinator conservation, their outcomes align with the conservation of pollinators and their habitats, and pollinator conservation can readily be integrated into these programs (and will generate greater benefit to Coloradans from them). Two excellent examples are the collaborative projects enhancing native plantings along I-76 following its designation as a Colorado Pollinator Highway, and the integration of pollinator-friendly provisions into relevant policies and management practices that resulted from the Administrative Order DNR-108. The management practices outlined in this report provide a valuable resource for implementing that directive.

There are also opportunities to strengthen or add state policies and programs to improve native insect pollinator conservation. Many of the recommended actions presented in this report are suggestions that state staff shared through survey responses, interviews, or discussions with the native pollinator study leadership team. The study team also relied on the synthesis of the current scientific knowledge, efforts implemented by other states, and the best available information to guide recommendations. Several examples of potentially high-leverage recommendations include pursuing the authority to manage pollinators and other insects as wildlife and establishing pollinator-related staff positions to support improved coordination across the state and through partnerships on pollinator-related efforts.

Future Priorities for Pollinating Insect Health & Management

Colorado has a unique opportunity to develop policies and actions that will support the health of pollinators and natural and agricultural ecosystems across the state. This study integrates the best available information about pollinator conservation, consultations with Colorado-based pollinator researchers, and input from state land managers. From this synthesis, we identify the five highest areas of immediate action and priorities the State should focus on for native pollinating insect health.

- Priority 1: Protect imperiled native pollinating insects.
- Priority 2: Protect, restore, and connect pollinator habitats.
- Priority 3: Mitigate environmental changes that negatively impact pollinators and their habitats.
- Priority 4: Reduce the risks from pesticides to pollinating insects.
- Priority 5: Monitor and support native and managed pollinator health.

While this study presents a tremendous amount of information on both the science and management of native pollinating insects, there are gaps in our understanding of both. To address the immediate need for action and the ongoing need for filling information gaps, the State should take a two-pronged approach to pollinator conservation by:

1. Taking immediate action to adopt current best practices and enhance agency policy and program recommendations, as described in this report, and
2. Continuing to investigate both the areas of impact that have not been fully studied and how management can best mitigate negative impacts.

Figure 3. Monarch butterfly (*Danaus plexippus*) flying over showy milkweed (*Asclepias speciosa*). (Photo: Xerces Society / Stephanie McKnight)

For the first part of this approach, implementation of the practices and program recommendations by the State, would represent a significant step towards conserving pollinators and their habitat. To ensure implementation and coordination, we recommend that each state agency with a role in pollinator conservation, develops a strategy and implementation plan based on the information and recommendations presented in this study. These plans can include:

1. How pollinator conservation can be integrated with the current work of the agency,
2. What activities the agency can take to help pollinators,
3. The resources such as funding, staffing, and expertise needed to implement these activities, and
4. How these agencies can work with other state agencies, nonprofits, researchers, extension and others to implement these activities.

As immediate actions are undertaken, the state should also simultaneously work on the second part of this approach by promoting research on the mechanisms of pollinator response to environmental change and integrating science into the practical application of management and conservation principles. This could be achieved through new collaborations between scientists and land managers to co-design studies with which to better inform science and management and to assess management outcomes.

Coupling agency-specific pollinator strategies and implementation plans with a statewide strategy to conserve declining pollinators would be a powerful combination to address pollinator conservation. As we gather more information about imperiled pollinators and those of greatest conservation need, Colorado Parks and Wildlife (CPW) and/or the Department of Natural Resources (DNR), working with researchers, nonprofits, and others, should develop a pollinator conservation strategy for rare and declining pollinators. This strategy could include:

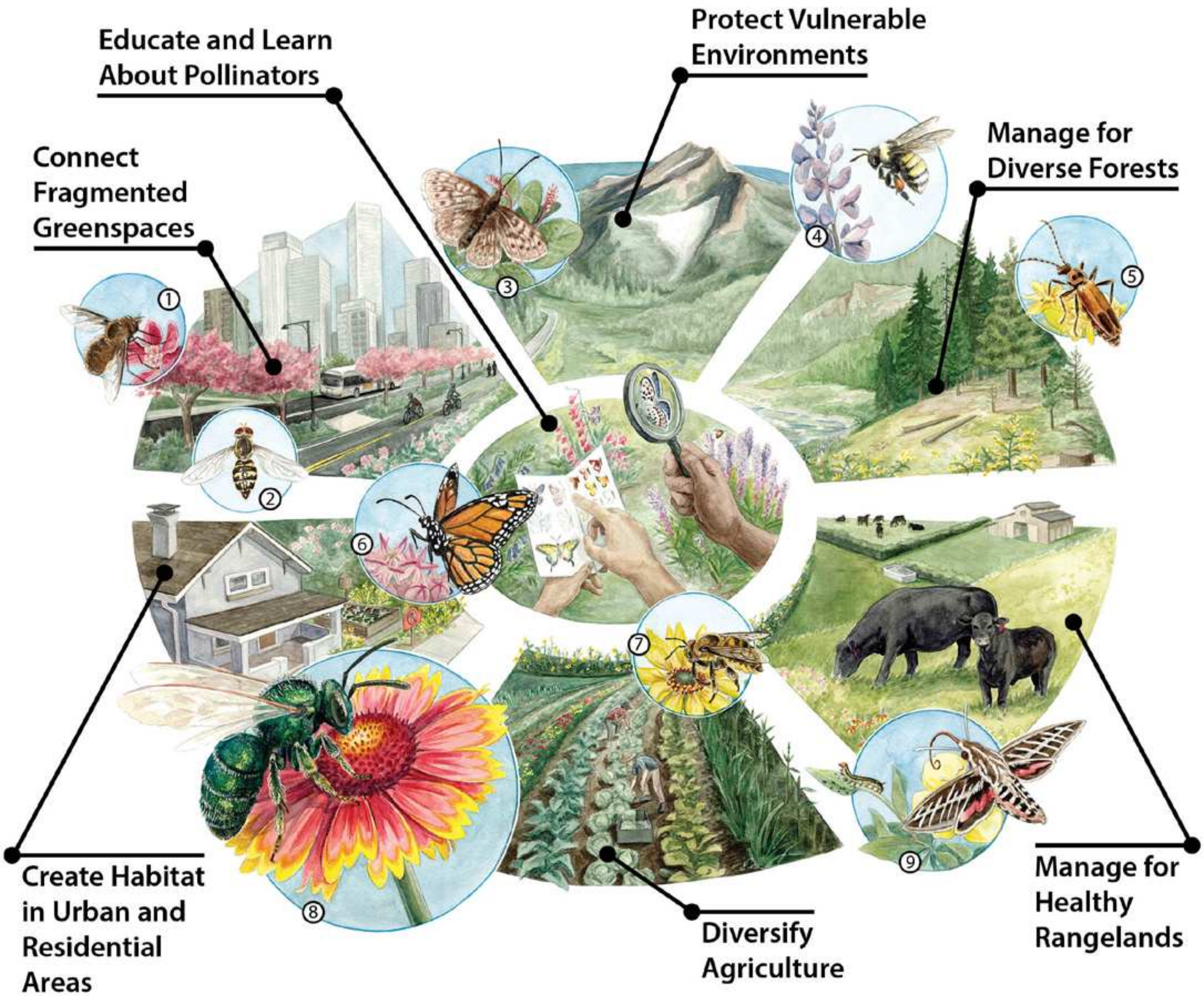
1. Identifying a list of priority imperiled bee and butterfly species that occur in Colorado,
2. Assessing threats for each,
3. Identifying priority areas for their conservation, and
4. Recommending habitat management and restoration actions on state lands to benefit these animals.

Policies and actions that address the current drivers of pollinator loss and fill gaps in our ability to protect pollinators will have a positive impact on pollinator health. Policies that address imperiled species are the highest priority, as these species are already suffering the worst impacts of human-caused environmental change.

Although CPW includes several pollinating insect species in the State Wildlife Action Plan (SWAP), the State lacks specific language granting authority over the management of insects or plants. Providing authority to DNR and/or CPW to manage insects fills a critical policy gap that is key to leveraging funding, resources, and the State's ability to protect the imperiled and other pollinators and their habitats. Colorado's pollinator expertise, diverse pollinator community, and extensive protected and semi-natural lands mean these strategies could be especially impactful in aligning state resources and partner organizations to work collaboratively to conserve and enhance the health of our pollinators and their many important services.

The State will need to invest significant resources into policy, action, and infrastructure. Luckily, the State is not alone in its efforts to address pollinator health. Pollinator conservation and management strategies can most effectively be developed and implemented in collaboration with the communities invested in the health of the state's native pollinating insects. By building new collaborations with local and federal government partners, researchers, non-governmental organizations, and others with pollinator expertise, the State can maximize the development speed and impacts of pollinator management and conservation efforts. This will also enable those partners to expand their impacts by scaling up their efforts to impact larger areas or more diverse communities across the state. By engaging with people across diverse constituencies, the State could better inform both agencies and the public about the importance of native pollinating insects in ecosystem and human health and promote conservation strategies that everyone can take to help protect them. Expanding these collaborations could also benefit the State's economy, fostering new research, creating new jobs, agricultural innovation, and supporting small businesses. The conceptual figure on the next page (the illustration is also featured on the cover of this report) represents the potential beneficial impacts of collaborative conservation action to address the most important areas of pollinator conservation needs. Ultimately, in following through with these actions, we hope this report will guide and support the State in efforts to ensure Colorado has healthy native pollinating insect communities now and into the future.

Pollinator Conservation: Collaborate for Success Across all Landscapes



Key actions to support healthy communities of insect pollinators

Collaborate among diverse groups including land-managers, policy-makers, scientists, advocates, and the public.

Take an adaptive approach to identify and resolve challenges to implementing pollinator conservation in varied landscapes and to balance the needs of people and pollinators.

Provide information and resources to empower agencies, organizations, and individuals to take action.

Featured Pollinators

1. Bee fly
2. Syrphid fly
3. Uncompahgre fritillary butterfly
4. Western bumble bee
5. Goldenrod soldier beetle
6. Monarch butterfly
7. Leafcutter bee
8. Metallic sweat bee
9. White-lined sphinx moth

XERCES SOCIETY for Invertebrate Conservation

Photo: Bureau of Land Management

Section 1. Introduction

1.1. Background to This Report

Colorado is home to a diverse community of native pollinating insects that contribute to the State's economy and enhance Coloradans' quality of life through the ecosystem services they provide. Their pollination services are the foundation of our food systems, they support overall biodiversity, and they are essential for other ecosystem services such as climate regulation, erosion control, and nutrient cycling. Pollinators also inspire curiosity and support recreation and tourism across the State. However, as important as native pollinating insects are, to date, no comprehensive assessment of their health or conservation status for the State has been conducted. With reports of major insect declines globally (Wagner et al. 2021), across the American West (Forister et al. 2021), and in Colorado (Dalton et al. 2023), the lack of a statewide synthesis of known drivers of pollinating insect declines, and strategies to mitigate them, is alarming. However, Colorado has been the center of a great deal of research on pollinating insects. In general, native bees have been the most studied pollinators in terms of their responses to environmental stressors, while more is known overall about the conservation status of butterflies than about other groups. Other pollinating insects, such as moths, beetles, wasps, and flies, are much less studied. Therefore, to better understand what is known about the status of native pollinating insects, their importance for natural resources, and how native insect pollinator communities across the state are changing, a comprehensive review of research is needed. Moreover, in order to understand how best to ensure Colorado has healthy and diverse pollinating insect communities, the State needs a synthesis of evidence-based best management practices in support of native pollinating insects, as well as an outline of state-agency policies or programs that address native pollinators.

Recognizing the need for coordinated state-level efforts, particularly among state agencies, the Colorado Department of Natural Resources (DNR) collaborated with stakeholders on a Pollinator Conservation Policy in 2018. This was a crucial first step by the State to acknowledge the critical role of pollinators and prompted further discussions regarding a comprehensive, coordinated program for the state. In response to growing concerns about native pollinator health in Colorado, during the 2022 legislative session, Senate Bill 22-199, the Native Pollinating Insects Protection Study, was introduced, sponsored by Senators Sonya Jaquez Lewis (District 17) and Kevin Priola (District 13) and Representatives Cathy Kipp (District 52), and Meg Froelich (District 3), in consultation with conservation organizations, scientists, and the DNR. This bill aimed to create a new framework for the state to assess native pollinating insects, by directing the DNR to conduct a study of state-agency resources and needs related to the challenges associated with supporting healthy populations of native pollinating insects. The bill was passed by the legislature and signed into law by Governor Jared Polis on May 27, 2022. The DNR subsequently commissioned this study, which was awarded to a collaborative team of pollinator researchers, managers, and conservationists. Their charge was to review the status of native pollinating insects within the state, and develop recommended land-management practices for their management and conservation. The outcomes of this study hold the potential to inform and chart a more robust course for protecting Colorado's native pollinating insects.

1.2. Study Team & Contributors

The broad scope of this study required the expertise and specializations of an interdisciplinary team of scientists, conservationists, and management professionals. The project was coordinated through Colorado State University Extension Service (CSU Extension), a highly successful statewide program providing information and training on Colorado's environmental, agricultural, and sustainability issues. The Xerces Society for Invertebrate Conservation (Xerces Society), the leading international nonprofit environmental organization that focuses on the management and conservation of invertebrates, collaborated on the development of recommended land management practices for pollinator insects. The University of Colorado Museum of Natural History (CU Museum) coordinated the scientific review. The museum has more than a century of expertise in Colorado native pollinating insect taxonomy, diversity, ecology, and natural history.

This team has been successful in integrating academic researchers with programmatic partners to ensure that the current independent science provides foundational evidence for developing effective programs, trainings, and outreach. This team has prior experience successfully collaborating with each other and multiple other partners. We have planned, presented at, and hosted the annual Colorado Pollinator Summit, a series of Front Range Native Bee Researcher Workshops, and the Landscaping with Colorado Native Plants Conference. Through collaboration we have developed guidelines and best management practices in combination with others, including state and federal agencies, for many Colorado landscape types. In addition to the team members and contributors outlined in this proposal, we consulted throughout the project with other researchers and practitioners from long-time working relationships with experts throughout the state and country. This collaborative approach brought together diverse experience, perspectives, and knowledge and provided a comprehensive and holistic set of recommendations based on a thorough scientific summary of what is currently known regarding native pollinator health in Colorado. It also enabled this study to outline gaps in our understanding, from both scientific and management perspectives, of how best to mitigate factors negatively impacting Colorado pollinating insects.

1.3. Stakeholders & Intended Audiences

Given the scope of this study, which is focused on statewide management and conservation of native pollinating insects, the intended audiences are state agencies, land managers within those agencies, and policymakers, all of which could take action based upon the recommendations of this study. However, many of the concepts and practices outlined in the study should be of broad interest to all Coloradans, especially those interested in the conservation of native pollinating insects. To ensure that the study team was leveraging the existing knowledge and expertise of the State's land management agencies, the team, along with DNR staff, identified key stakeholders within the State to engage in developing the study. Key among them are the State's Departments of Agriculture, Transportation, Public Safety, and Public Health and Environment, and DNR divisions including Parks and Wildlife, State Forest Service, and the State Land

Board. An ad hoc committee of state agency leadership was created, and served as advisors throughout the study. The committee was invited to monthly meetings and was provided with monthly progress reports throughout the course of the project. As the study team moved into drafting the final report, the leadership committee served as reviewers of study content as it was being developed and provided comments and edits that helped in the overall conceptualization of the report. In addition, representatives from the aforementioned State departments provided valuable feedback via an online survey and virtual one-on-one interviews, which informed the management practice, policy, and program recommendations shared in this report. Several federal agency representatives also participated in an online survey to help inform study recommendations. The survey and interview results were integral to tailoring Colorado-specific recommendations on management practices, and in prioritizing areas of action for future research, management, and policy.

Colorado has some of the most renowned pollinator scientists and research institutions in the nation, although a compilation of their research for Colorado does not exist. This study addresses this critical gap; it includes a comprehensive review of existing pollinator-related science, focusing particularly on research done within Colorado. The scientific review utilizes local expertise and scientific knowledge, contextualized with national and global analyses of mechanisms impacting pollinators. This synthesis was used to inform the recommended management practices included in the study. Moreover, it has helped to identify the most critical research needs, such as current and new long-term monitoring efforts capable of tracking pollinator health and diversity through time. The scientific review should be of interest to land managers and conservationists alike, in order to understand how best to direct efforts to improve pollinator health, in coordination with the development of best management practices.

Although this report is focused on published research to inform the development of recommended management practices for pollinating insects, it should be noted that there is a wealth of experience, information, and knowledge within the broader educational and conservation communities across the state. Many nonprofit organizations and community groups have significantly invested in Colorado pollinating insects, with work and efforts either directly related to, or supporting, pollinator conservation and education. While mostly outside of the scope of the scientific review, the study team engaged with these communities through the Colorado Pollinator Network, a collaborative network linking many groups and the public, to offer an opportunity to provide insight into their work.

1.4. Report Organization

This report is organized into a number of broad sections, which we outline below. These sections were compiled to the best of our team's abilities and within the scope of this study, to summarize what is known about native pollinating insects in Colorado, and how they have been incorporated in the management and conservation programs of state agencies.

In the **Scientific Review (Section 2)**, we first review the importance of native pollinating insects to both agricultural and natural resources within the state (2.1). We then briefly explore the diversity and distribution of pollinating insects, review evidence of declines, and highlight species of special conservation concern (2.2). The bulk of the review summarizes the tremendous body of research on Colorado's native pollinating insects (2.3), focusing on factors that negatively impact them, but also on where research has explored ways management can help mitigate those impacts. We then summarize the state of Colorado's native pollinating insects (2.4), and discuss gaps and potential future directions for both research and management. To note, these subsections do not necessarily align with the subsections of the other broad sections below, as the majority of scientific research in Colorado has been conducted from an ecological or mechanistic perspective, and not necessarily organized by habitat type or management technique. This underscores the need for more collaboration between scientific researchers and land managers.

In **Conservation Practices (Section 3)**, we first outline general considerations for incorporating pollinating insects into conservation and management programs (3.1), and how to apply concepts from the scientific understanding of both pollinating insects needs and management impacts. We then provide the recommended management practices for pollinating insects developed for Colorado (3.2), and share the results of the pollinator conservation practices that are currently being used, barriers that could be addressed to increase the implementation of practices, and implications for the state agencies. We follow with the results of our review of state agency programs, policies, and current recommendations that address pollinators (3.3), in order to highlight where action has already been developed and where future recommendations could be implemented. This includes a review of statewide policy and programs that are guiding or could guide pollinating insect conservation (3.4). A brief review of federal programs (3.5) that are oriented to pollinator conservation is also provided in this section of the report.

In **Future Priorities for Pollinating Insect Health and Management (Section 4)**, we discuss the potential outcomes from this report, including suggested priorities for Colorado native pollinating insect health (4.1), ways to foster more collaborative conservation and management practices (4.2), and potential resources necessary for the State to act upon the recommendations within this report (4.3).

In summary, this study is a synthesis of the best available information, stakeholder engagement, and engagement with state staff to develop a better understanding of native pollinating insects in Colorado and how state agencies can address pollinators in their programs and practices. While every effort was made to incorporate as much data, research, and programs of interest as possible, the study was limited by the time and funding constraints of the award and should therefore not be considered an exhaustive compilation. For example, new research studies are being published and new programs are being created (e.g., National Native Bee Monitoring Network 2023) to address native pollinating insects. Ultimately, this study provides an opportunity to develop a framework of knowledge and recommendations that can be built upon to not only improve the focus and success of state agency pollinator-conservation programs, but also provide information that is applicable for private landowners, local governments, and federal agencies. The outcome of this study demonstrates how efficiency and effectiveness can be improved through shared objectives and collaborative work. Within the following pages of this report, you will find the most comprehensive review of the existing research on Colorado pollinators ever conducted, along with the management practices and recommendations for pollinator conservation on state-managed lands and beyond.

Photo: Adrian Carper

Section 2.
Scientific Review of Colorado Native Pollinating Insects

Native pollinating insects are a fundamental component of Colorado's agricultural, natural, and cultural resources, helping support the sustainability of crops, the stability of our natural areas and ecosystems, and the health and well-being of the state's residents and visitors. However, although public concern over the conservation status, health, and diversity of pollinating insects has grown in recent years, the need for evaluation of Colorado's native pollinating insects has received less attention. To ensure the state has a healthy, diverse, and sustainable pollinating insect community, we must assess the current condition of our native pollinating insect communities and determine whether there are conservation concerns that need to be addressed.

This Scientific Review has compiled information from Colorado-specific studies of pollinating insects, their importance to agriculture, their diversity, current conservation status, and major drivers of their populations and communities across the state. Although the focus of this review is statewide (e.g., studies that have been conducted within Colorado or that include data collected from Colorado), the scope of scientific literature included is global in nature, to add context to the results that have been found within Colorado, and to highlight gaps in our understanding of Colorado-specific pollinators and the factors that impact them.

The vast majority of the information provided within this review comes from the published scientific literature, i.e., peer-reviewed professional publications, which require rigorous scientific and editorial scrutiny before publication, to ensure that the evidence presented, and the conclusions drawn, are scientifically accurate. In addition, we also include student research, such as graduate student theses and dissertations, which have similarly been scrutinized by a committee of academic professionals, to ensure that the results presented are accurate and warrant publication by the university (e.g., theses or dissertations). Other findings that have been included come from research conducted as part of government-sponsored projects requiring a published final report (e.g., small research grants from city or county governments). These reports can be valuable as they are often focused on a specific management area or topic, such as the impacts of a particular management strategy on pollinators in a particular place. Many of these studies go on to be published in peer-reviewed publications, but given the short timeframe of this study, we felt it appropriate to include them as relevant, Colorado-specific data. Finally, we also present and synthesize publicly available data from the government, online databases, and biodiversity data aggregators. These data include citations for their sources, download dates, and all associated data files included in the appendices or shared with the Department of Natural Resources so that anyone can review the data presented herein.

Figure 2.1. University of Colorado Boulder researchers on Niwot Ridge (over 12,000 ft. [3,800 m] in elevation) race to study pollinators such as this bumble bee (*Bombus* sp.) (right), before an approaching storm reaches them. (Photos: Adrian Carper.)

2.1. The Importance of Colorado Pollinators

Pollinating insects are intricately tied to the health of our natural ecosystems and the sustainability of our agricultural commodities, but also the health and well-being of our state's residents and visitors. While few studies have linked all of these mechanisms together, the current scientific understanding of the importance of pollinators to humans acknowledges that **there are strong connections between pollinator health and human health**. These connections are driven by the roles that pollinators play in helping maintain nutritionally diverse crops and food, sustaining a diversity of plants with potential medicinal uses, and supporting our natural ecosystems that provide the goods and services we depend on—all supporting human physical and mental health and well-being (Garibaldi et al. 2022).

2.1.1. Agricultural Resources

Pollinating insects have long been acknowledged for their importance to our agricultural systems. Globally, more than a third of the world's crops depend on pollinators, mostly insects, to produce seeds or fruit (Klein et al. 2006). These crops, including most fruits and vegetables, provide essential nutritional diversity to our diets and bodies (Eilers et al. 2011) and are a dominant component of the global economy, valued at $34 billion in the United States alone (Jordan et al. 2021), with agriculture in general becoming increasingly dependent on pollinators worldwide (Aizen et al. 2019). The managed European honey bee (*Apis mellifera* L.), which was historically kept to produce hive products such as honey and beeswax, has become a dominant driver of pollination services to crops. However, wild pollinating insects, i.e., those not managed specifically by humans for crop pollination, are estimated to contribute to the production of some $4.59 billion in crop production in the United States (Calderone 2012), with some crops, such as tomatoes and peppers, nearly entirely dependent on native pollinating insects.

Within Colorado, pollinating insects contribute to billions of dollars worth of agricultural production. Colorado is an agriculturally intensive state, with approximately 38,800 farms operating on approximately 31.8 million acres (12.8 ha) of land (USDA/NASS 2023a), and producing nearly $3 billion worth of crops annually ($2.96 billion in 2021, USDA/NASS 2023b). Some Colorado crops primarily depend on insects for pollination and fruit production. Colorado peach growers produced 1,370 tons of peaches in 2022, valued at more than $33.9 million (USDA/NASS 2023a,c), and peaches and other tree crops, such as apples, apricots, and cherries, are most effectively pollinated by early season mason bees (in the genus *Osmia*). For many crops, native bees are highly effective pollinators, producing more and larger fruit than managed honey bees (Mallinger and Gratton 2015; MacInnis and Forrest 2019; Nicholson and Ricketts 2019). Field crops can also benefit from insect pollination. For beans, peas, soybeans, sunflower, and safflower, for instance, while insect pollinators are not necessarily required to make fruit, all produce bigger or have more fruit/seeds with insect pollination, increasing yields. Sunflower fields covered more than 53,000 ac. (21,450 ha) in Colorado in 2022 and were valued at nearly $13 million (USDA/NASS 2022a); beans were valued at $27.9 million in 2021 (USDA/NASS 2023d). Moreover, certain vegetable crops, such as peppers, tomatoes, eggplant, and squash, are best (and sometimes only) pollinated by native pollinating insects. Tomatoes and peppers for example, even if self-compatible (i.e., not requiring pollen from another plant to make fruit), still depend on native bees to buzz-pollinate flowers to set fruit. In buzz-pollination, wild bees grab onto flowers and buzz, vibrating the flower to release pollen; honey bees cannot buzz-pollinate. Crops in the cucumber family, like Rocky Ford cantaloupes, are best pollinated by squash bees (*Eucera*, *Xenoglossa*, and *Peponapis* spp.) which co-evolved with squash in western North America and have specialized structures for collecting and transporting squash pollen. And even other non-specified vegetable crops, valued over $27 million (USDA/NASS 2023d), likely benefit either directly or indirectly from insect pollination.

Figure 2.2. Squash bees, like this *Peponapis pruinosa*, can often be found sheltering within the flowers of squash and melon crops, where they are a specialist on squash pollen and also their most effective pollinators. (Photo: Adrian Carper.)

Moreover, these numbers don't include alfalfa, hay, and other agricultural products that support the livestock industry. Alfalfa, grown as protein-rich livestock feed, is particularly dependent on pollinating insects for seed production. In order for an alfalfa flower to be pollinated, a bee must trip the flower's anther, held under pressure, which then springs up, becoming accessible for pollination (See Figure 2.11, under Introduction to Pollination and Pollinating Insect Diversity [2.2.2], for a diagram of plant structures involved in pollination). Alfalfa leafcutter bees (*Megachile rotundata*) are currently the preferred pollinator for alfalfa, pollinating ~80% of the flowers they visit compared to honey bees, which pollinate only about 20% (Cane 2002). Alfalfa leafcutter bees were accidentally introduced from Europe sometime before the 1940s, so are not native to North America; however, they are now managed for alfalfa pollination and even in areas where not specifically managed, make up a dominant component of the wild bee community, especially in agricultural regions. In Colorado, over three-quarters of the 1.02 million acres dedicated to growing hay are composed of alfalfa (780,000 acres), which is valued at nearly $700 million (USDA/NASS

2023a), which, along with other hay and grazed lands, contributes to over $5 billion in livestock production across the state (USDA/NASS 2022b).

2.1.2. Natural Resources

In addition to concern over the sustainability of agricultural pollination, there have been major concerns over the stability of plant–pollinator interactions, and subsequently the sustainability of pollination as a critical ecosystem service since before the turn of the twenty-first century (see Kearns et al. 1998). Globally, approximately 85% of flowering plant species depend on pollinators, again mostly insects, to make fruit and seed (Ollerton et al. 2011), and in turn they support entire ecosystems of diverse plants and animals (Ollerton 2017). The value of native pollinating insects to Colorado's natural resources is difficult to estimate, as they occupy an irreplaceable role within our natural areas, but is likely in the billions of dollars. Humans benefit directly from more biodiverse ecosystems, which can produce more goods (e.g., better grazing, as well as more and healthier wildlife or other harvested natural resources) but also indirectly through increased ecosystem services (more pollination, better soil and water conservation, and climate regulation) (Mace et al. 2012). Interacting with nature also has numerous psychological, cognitive, physiological, and social benefits such as improved mood, reduced stress, fewer postoperative complications for surgical patients, and a greater sense of social cohesion (Keniger et al. 2013).

Figure 2.3. Agricultural Importance of Native Pollinating Insects: Native pollinating insects contribute to the value of agricultural production by providing pollination services to pollinator-dependent crops such as cantaloupe and peaches, by improving yields in other crops such as oil seeds and beans, and by helping sustain alfalfa, hay, and rangelands that support the livestock industry. Valuation of crops and livestock from USDA NASS 2017 Census of Agriculture Colorado State Profile (USDA/NASS 2017).

Pollinators benefit natural habitats such as Colorado's forests mostly by indirect means. Ground-nesting pollinators such as solitary bees, for instance, physically change the soil texture by digging tunnels and cavities, but the rest of pollinators' effects on soil health are by means of pollinating plants on the forest floor. These insect-pollinated plants on the forest floor reduce water runoff, recharge underground aquifers, help filter pollutants from the environment, and provide habitat for countless soil-dwelling organisms such as earthworms, ants, and even the mycorrhizal fungi that help trees grow (Christmann 2022).

Figure 2.4. Native pollinating insects are crucial to Colorado's natural resources and help drive its thriving recreation and tourism industry, with people willing to, quite literally, go to great heights to catch a glimpse of stunning wildflowers. (Photo: Adrian Carper.)

Biodiverse landscapes, aided by pollinators, also contribute to tourism within Colorado, though it is difficult to measure exactly how much of Colorado's tourism is wildflower tourism or ecotourism more generally. For example, Crested Butte, considered the "Wildflower Capital of Colorado," has a very successful 10-day Wildflower Festival in July of each year, offering over 200 workshops on a variety of topics, including pollination. This festival attracts thousands of visitors every year who, in addition to attending workshops, visit vendors and engage in tours, art, performances, and food, all centered around the importance of wildflowers to the community.

2.2. Declining Pollinators

Given the reliance of our agricultural and natural ecosystems on pollinating insects, there have been long-running concerns over pollinator declines globally (Potts et al. 2010) and recently increasing evidence that points to global, regional, and local declines in insects, including pollinators. In a review of 73 historical reports of insect decline around the world, researchers found that all types of insects are exhibiting some levels of decline, mostly driven by human caused habitat loss, pollution and pesticides, introduced species, and climate change. On average, 40% of insect species—with between 8% and 68% of species within dominant taxonomic orders—are considered in decline by the International Union for Conservation of Nature (>30% decline), with concurrent reports of declining insect abundance, diversity, and health (Sánchez-Bayo and Wyckhuys 2019; Wagner 2020). Locally, even within a protected high-elevation meadow outside Crested Butte, over the last 35 years, insect biomass has declined by ~47% and abundance by ~61.5%, driven primarily by lower summer precipitation and winter snowfall, as well as warmer temperatures in general (Dalton et al. 2023, Figure 2.5). This meadow is owned by the Rocky Mountain Biological Laboratory (RMBL), has been fenced to exclude cattle for 35 years, and is 0.75 mi. (1.2 km) away from the nearest heavily traveled trail in the surrounding landscape mosaic of United States Forest Service land and private conservation-easement land. This suggests that even in Colorado's protected wildlands, insects are under pressure from the negative impacts of human environmental change, such as climate change, land-use change, and pesticides.

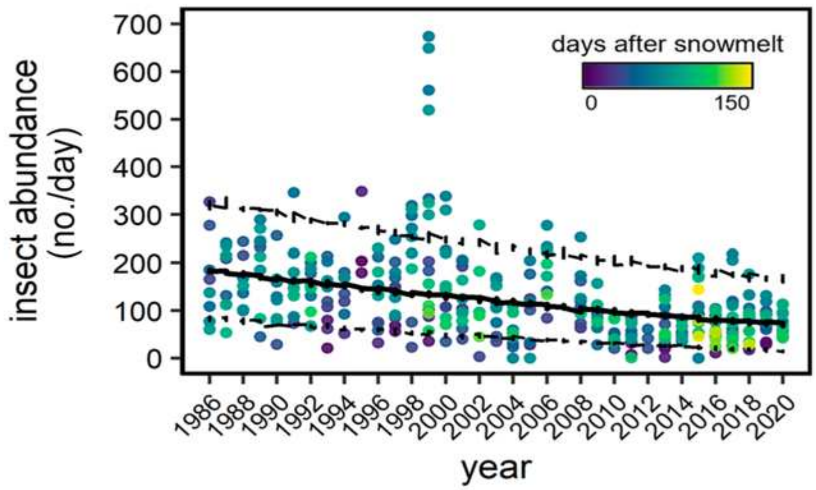


Figure 2.5. Decline in insect abundance over 35 years in a subalpine meadow outside of Crested Butte, CO. (Reproduced from Dalton et al. 2023, CC BY 4.0.)

2.2.1. Species of Concern

Comparative Studies

In Colorado, few comparative studies of pollinator communities through time exist to understand precisely how our native pollinating insect communities have changed. Studies that have been conducted have compared historical collections of bees to contemporary sampling. For example, the Resasco lab at CU Boulder is resampling a historical study (Clements and Long 1926) on plant–pollinator interactions on Pikes Peak (www.colorado.edu/lab/resasco/pikes-peak-plant-pollinator-project). Another study of bee species found in open spaces around Boulder compared bee species then occurring with a countywide species list of bees recorded a century earlier by T. D. A Cockerell in *The Bees of Boulder County* (Cockerell 1907). The authors concluded that protected open spaces may still harbor as diverse bee communities as historically, likely as a result of their very protection (Kearns and Oliveras 2009). However, studies comparing historic versus contemporary sampling of bees suffer from a number of biases, for instance, the shift in study methods toward collecting more social or generalist pollinators (by means of traps and unskilled collection) compared to early researchers' focus on diversity and specialist species. This collection bias may overestimate the resiliency of at-risk groups and underestimate the vulnerability of solitary or specialist species (Goldstein and Scott 2015).

Long-term sampling of pollinators with consistent methodology is currently being conducted in Gunnison County, based at RMBL. For example, surveys of the altitudinal distributions of bumble bees (Bombus spp.) in the East River valley from the 1970s (Pyke et al. 2011, 2012) were replicated decades later and queens were found to have moved up a few hundred meters in altitude, probably because of warming temperatures (Pyke et al. 2016). An ongoing re-survey of butterflies is also in progress, following up on data from the 1980s.

A more recent project with sampling sites from the sagebrush to the subalpine is being paired with flowering and weather data to explore how plant and pollinator communities are changing (see Section 2.3). However, this sampling has only been occurring for 14 years. Although we lack a historical comparison for it, the study has already created a baseline and 14 years of continuous monitoring, with trends in some groups already apparent (see 2.3.9 Climate Change). Continuing these and other monitoring efforts over longer time series with consistent collecting is especially needed to determine bee population trends. Moreover, creating similar monitoring programs in important and often under surveyed ecoregions within the state, including grasslands, alpine, and xeric (dry) habitats is needed to more comprehensively understand how pollinator communities are changing through time. Clearly, more long-term studies are needed.

Species of Concern

Globally, many pollinating insects are declining and Colorado is no exception. Bumble bees, for example, are declining in their distributions, local populations, and individual colony health due to a combination of habitat loss caused by agriculture and urbanization, climate change, pathogens, non-native species, and pesticides, with approximately a quarter of all North American bumble bees now considered as Threatened on the IUCN Red List (Cameron and Sadd 2020). This list includes the western bumble bee (*Bombus occidentalis*), rusty patched bumble bee (*B. affinis*), and American bumble bee (*B. pensylvanicus*) (IUCN 2023). The true scope of decline, especially locally, is hard to determine. Bumble bee populations are highly variable in space and time, making detecting long-term trends difficult. For instance, in a five-year study across sites at different elevations across Boulder County, researchers found no decline in abundance over the study period, although the relative abundances of bumble bees among sites varied dramatically from year to year, suggesting that both environmental factors and potentially species interactions drove changes in the bumble bee communities through time (Kearns et al. 2017). An eight-year study of three bumble bee species in Crested Butte similarly found no directional population trends over time (Ogilvie et al. 2017), but the fact that the bees did not respond identically to variation in climate and floral resources suggests that even within bumble bees as a group, generalizations are difficult. Because populations are so highly variable from year to year, longer time series than five or eight years will likely be needed to detect trends. However, for some species, concerns are clearly justified. **Over 20% of Colorado's 24 bumble bee species are currently petitioned or under review by the United States Fish and Wildlife Service (USFWS) for listing under the Endangered Species Act (ESA).** As of the drafting of this report, the American bumble bee (*B. pensylvanicus*), the variable cuckoo bumble bee (*B. variabilis*), the western bumble bee (*B. occidentalis*), and Suckley's bumble bee (*B. suckleyi*) are all under review by the USFWS for listing under

Figure 2.6. Bumble bees of concern in Colorado include the western bumble bee (*Bombus occidentalis*) and American bumble bee (*Bombus pensylvanicus*). (Photos: [l] Stephen Ausmus, USDA ARS; [r] Xerces Society / Katie Lamke.)

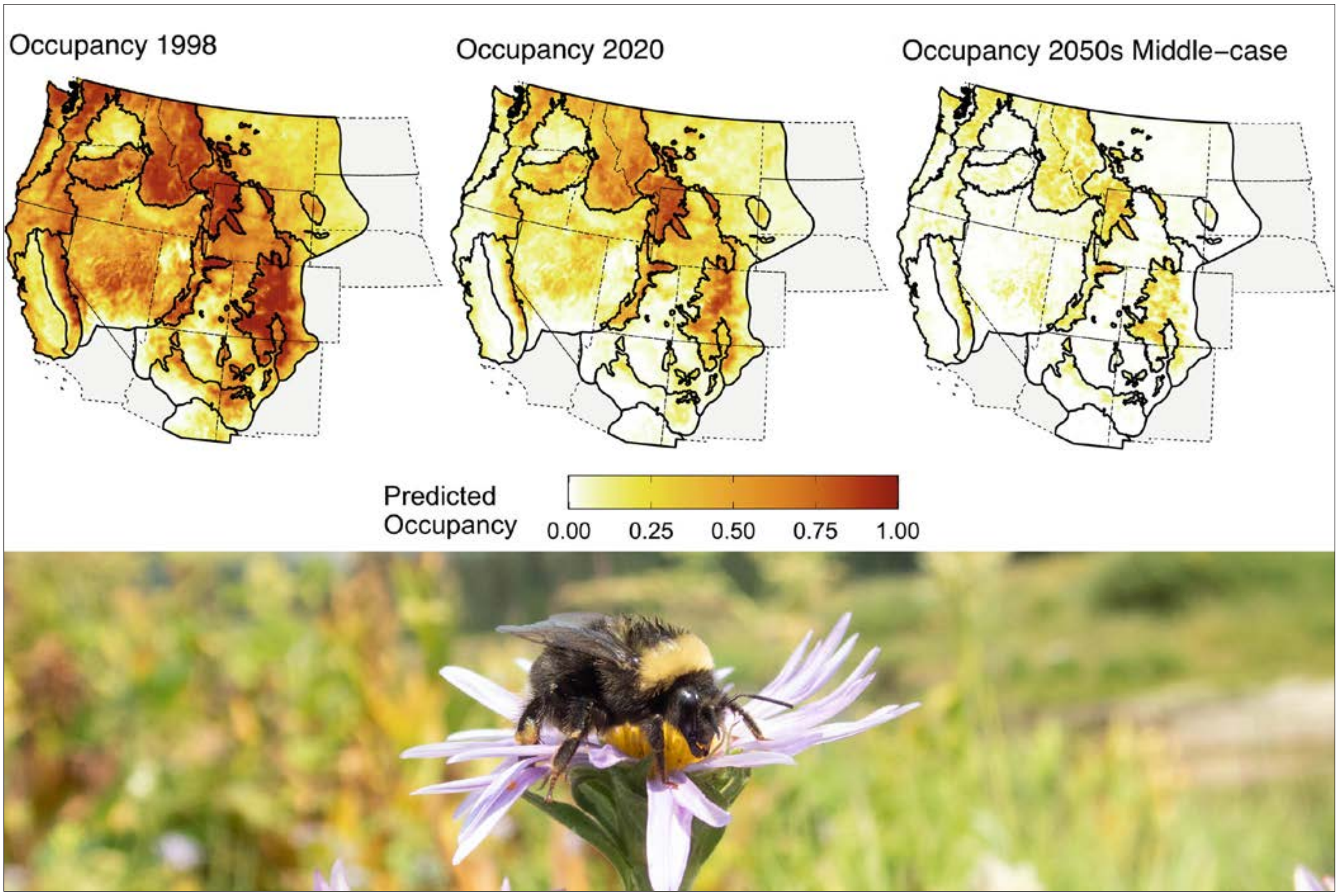


Figure 2.7. The western bumble bee, *Bombus occidentalis*, is in decline over most of its range, with modeled distributions declining from 1998 to 2020 and projected to decline much further by 2050, even under moderate scenarios (adapted from Janousek et al 2023). The species is currently under review by the United States Fish and Wildlife Service for federal protection under the Endangered Species Act. (Photo: Rich Hatfield.)

the ESA, and the southern plains bumble bee (*B. fraternus*) has been petitioned for listing. Some of the strongest data available are for the western bumble bee, which has declined by 57% from its known range in just a little more than 20 years, driven primarily by increasing temperatures and drought across the west, and the use of neonicotinoid pesticides, with projected future declines of up to 97% by 2050 (Janousek et al. 2023). Importantly, many other native bee species within the state are much more narrowly distributed than any of these bumble bee species, with much smaller populations, but few data are available to assess their conservation status.

Several butterfly species in Colorado are of concern due to their limited geographic range, specific requirements for habitat, or both. The Nokomis fritillary (*Argynnis nokomis nokomis* [formerly known as the Great Basin silverspot]) is a black-and-white butterfly whose range includes parts of eastern Utah, northern New Mexico, and western Colorado. It is currently proposed as Threatened by the USFWS under the ESA. This butterfly only lives in mountain valley streamside meadows between 5,200 and 8,300 feet in elevation, laying its eggs on bog violets (*Viola nephrophylla*, Violaceae).

With an even smaller geographic range, the Pawnee montane skipper (*Hesperia leonardus montana*) is considered Threatened by the USFWS. This small orange butterfly is endemic to the South Platte River drainage system in Douglas, Jefferson, Park, and Teller counties southwest of Denver. Pawnee montane

Figure 2.8. Butterfly species of concern in Colorado include (left to right) Nokomis fritillary (*Argynnis nokomis nokomis*), Pawnee montane skipper (*Hesperia leonardus montana*), and Uncompahgre fritillary (*Boloria improba acrocnema*). (Photos [l–r]: Robb Hannawacker; USDA Forest Service; Bill Bouton.)

skippers require blue grama grass (*Bouteloua gracilis*, Poaceae) to lay their eggs on and rely on the prairie gayfeather (*Liatris pycnostachya*, Asteraceae) for nectar as adults.

The smallest geographic range of any North American butterfly is that of the Uncompahgre fritillary (*Boloria improba acrocnema*). This orange, brown, and black butterfly is native only to high alpine habitat in the San Juan Mountains of Colorado and is listed as Endangered by the USFWS. These butterflies lay their eggs on or near snow willows (*Salix nivalis*, Salicaceae), but their range is much more constrained than that of their host plant. Research to identify the habitat requirements of this very rare species is ongoing.

A number of other butterfly species are currently being considered for protection under the ESA. For example, the regal fritillary (*Argynnis idalia*, syn. *Speyeria idalia*) is currently under review for listing, and the monarch (*Danaus plexippus*) is listed as a candidate species, given its narrow host range on milkweeds (*Asclepias* spp.) and extraordinary migratory behavior. Fourteen pollinator species of concern in Colorado are further profiled in Appendix IV.

2.2.2. Introduction to Pollination & Pollinating Insect Diversity

Pollination is the process that most plants use to reproduce. Pollination is one step in the life cycle of these plants that allows for movement to find mates. For flowering plants (also called angiosperms), pollen grains are produced in the stamens (structures that produce pollen) of a flower, and can be carried away by the wind, animals, or even water. If a pollen grain lands upon a compatible flower, particularly the pistil (structures that contain ovules, female reproductive parts), then this can result in a seed that contains the embryo of a new plant generation. Along with the great diversity of flowering plants comes a diversity in pollination systems. Some flowers are designed so that the stamens of each flower deposit pollen onto the pistil of the same flower, resulting in what is known as self-fertilization. Other plants require a very specific animal to deliver pollen. And many plants use a combination of approaches. Though self-fertilization is common, and some plants can even skip sexual reproduction and produce clones (genetically identical new plants), pollination results in the mixing of genetic material in plants, which is extremely important for maintaining healthy plant populations that are genetically diverse and can adapt to environmental change.

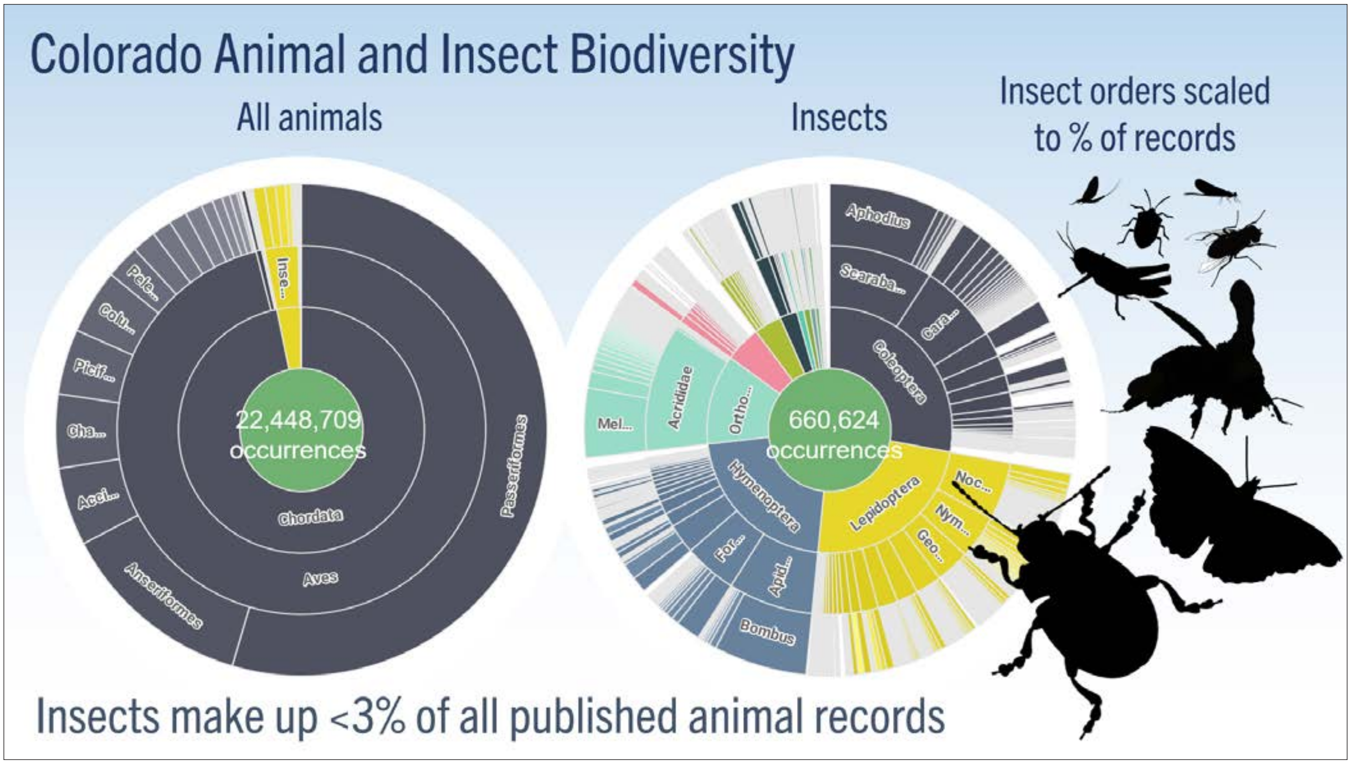


Figure 2.9. Conservation statuses for insects typically use distributional knowledge, derived from published data on georeferenced occurrences. However, of the more than 22 million records of animals published from Colorado, fewer than 3% are insects, meaning that our ability to ascribe a conservation status to most species is limited by our understanding of where and how often they occur. (Colorado data from GBIF.org.)

Any insect that visits multiple flowers can function as a pollinator. For the most part, these insects visit flowers in order to obtain food, either from the flower itself or from other insects also visiting the flower. For most floral visitors, nectar serves as their sugar source and pollen serves as their protein source. Bees are such successful and important pollinators because they have evolved to eat only pollen as a protein source (with very few exceptions) and have specifically adapted hairs and body parts to transport pollen, making bees highly reliant on flowers and usually reliable as pollinators. However, pollen is often sticky and may adhere to the body of many insects that visit flowers with some then being deposited onto other flowers that the insects visit. Many flowers are shaped in ways that maximize the chances that pollen will be carried by visiting insects and be deposited in the right place on other flowers. Flowers also advertise to attract potential pollinators. The bright colors and unique shapes of flowers signal to pollinators that there is sugar-rich nectar and protein-dense pollen to be found.

Pollinating insects often have resource needs that change throughout development. All of the major insect groups that are generally considered to be pollinators are holometabolous, meaning that they

Figure 2.10. (facing page) A selection of Colorado butterflies photographed using 2D focused stacked macrophotography in the University of Colorado Museum of Natural History Entomology Collection.

Left (top to bottom): mourning cloak, *Nymphalis antiopa*; silver-spotted skipper, *Epargyreus clarus*; Sheridan's hairstreak, *Callophrys sheridanii*; pine white, *Neophasia menapia*; common ringlet, *Coenonympha tullia*; painted lady, *Vanessa cardui*.

Middle (top to bottom): Colorado hairstreak, *Hypaurotis crysalus*; monarch, *Danaus plexippus*; western tiger swallowtail, *Papilio rutulus*; silvery blue, *Glaucopsyche lygdamus*; Rocky Mountain parnassian, *Parnassius smintheus*.

Right (top to bottom): Weidemeyer's admiral, *Limenitis weidemeyerii*; Sara orangetip, *Anthocharis sara*; dainty sulphur, *Nathalis iole*; western pine elfin, *Callophrys eryphon*; common buckeye, *Junonia coenia*; Milbert's tortoiseshell, *Aglais milberti*.

undergo a dramatic transformation between the immature (or larval) and adult stages, known as complete metamorphosis. These insects also undergo pupation, which is a transitional stage between larvae and adults, during which the animal is largely immobile. Immature insects of these groups, known as larvae, generally look very different from adults and have different needs. Caterpillars, for example, are the larvae of moths and butterflies, and typically feed on plant leaves. These larvae cannot fly and likely do not pollinate flowers. However, adult butterflies and moths are strong fliers and capable of transporting pollen over great distances. While it is generally only the adults that visit flowers, healthy pollinating insect populations must have access to all the resources needed to support them throughout their development.

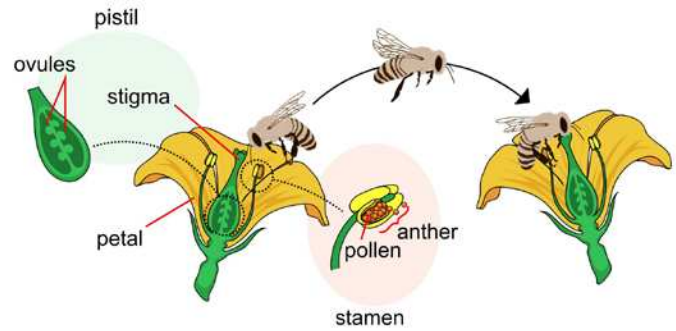


Figure 2.11. Flower parts involved in pollination. Pollinating insects make contact with the anthers of flowers (accidentally or purposely to collect pollen) and pick up pollen grains. Upon visiting another flower of the same species, some of these pollen grains may be deposited onto the stigma. This can result in the production of seeds in the ovules of the second flower. This is an example of flowers that contain both male and female structures. In some plant species, those are present only in different flowers.

While butterflies are highly visible flower visitors and get a great deal of attention as pollinators, moths are also widespread pollinators (both order Lepidoptera). Many moths visit flowers at night and so are likely to be more important pollinators than is currently understood. Sphinx moths (family Sphingidae) and some kinds of owlet moths (family Noctuidae), such as miller moths, pollinate flowers as they search for nectar. Yucca moths (family Prodoxidae) are in a highly specialized symbiotic relationship with yucca plants (*Yucca* spp.)—the yucca plant and yucca moth need each other and cannot survive apart from each other (see Box 2, about yucca pollination, in section 2.2.3, below). Some species of butterflies and moths do not feed as adults, but those that do generally visit flowers for nectar. Unlike many other pollinators, pollen-feeding is very rare in butterflies and moths. Caterpillars, the larvae of butterflies and moths, mostly feed on plants, and some require very specific plants or groups of plants in order to successfully grow to become adults. Because of this, butterflies and moths are generally highly sensitive to changes in plant communities. Some species also pupate underground and so require the right soil conditions.

Figure 2.12. A white-lined sphinx moth (*Hyles lineata*), a very common day-flying moth in Colorado, visiting an arctic gentian (*Gentiana algida*). (Photo: Adrian Carper.)

Flies (order Diptera), such as mosquitoes (family Culicidae), flower flies (family Syrphidae, also called hover flies), bee flies (family Bombyliidae), soldier flies (family Stratiomyidae), some tachinids (family Tachinidae) and many muscid flies (family Muscidae) drink flower nectar and pollinate flowers as they do. **Flies are important pollinators at high elevations, where they are often the most common flower visitors.** Orchids such as the spotted coral root (*Corallorhiza maculata*), found in Colorado, sometimes rely

Figure 2.13. A selection of flies visiting flowers (left to right): a mosquito (family Culiciidae) with pollen on its proboscis; a bee-mimicking flower fly (family Syrphidae) visiting a penstemon flower; and a crane fly (family Tipulidae) visiting flowers of *Ligusticum porteri*—although it's not known how well it pollinates the flowers. (Photo: [l, r] David Inouye.; [c] Adrian Carper.)

on flies as pollinators, attracting them with foul smells, while other orchids have sweet scents that attract mosquito pollinators (e.g., *Platanthera obtusata*). While not as well studied as bees and butterflies, flies are extremely diverse, and likely play important roles as pollinators in both natural and agricultural systems (Inouye et al. 2015). The larvae of flies also have a great variety of life styles. Tachinid and bee fly larvae are generally parasitoids, which grow inside of other insects, while flower fly larvae can eat other insects or even fungi.

Beetles, especially hairy or fuzzy beetles, can be effective pollinators. Though underappreciated as pollinators, beetles (order Coleoptera) evolved before bees and butterflies, were some of the earliest pollinators of flowering plants, and remain important today. Beetle pollinators include some kinds of scarab beetles (family Scarabidae) and metallic wood-boring beetles (family Buprestidae), longhorn beetles (family Cerambycidae), sap beetles (family Nitidulidae), checkered beetles (family Cleridae), blister beetles (family Meloidae), and soldier beetles (family Cantharidae). Adult beetles visit flowers for various reasons, including to feed on pollen, nectar, and even petals, and to feed upon other insects that are visiting flowers. Some pollinating beetle-larvae bore into wood, while others are predatory and feed on other insects, and many live in the soil.

Figure 2.14. Kern's flower scarabs (*Euphoria kernii*) are often found in great numbers inside of prickly pear cactus (*Opuntia* sp., Cactaceae) flowers. (Photo: Whitney Cranshaw, Colorado State University, bugwood.org, CC BY 3.0.)

Overshadowed by their bee relatives, wasps (order Hymenoptera, suborder Apocrita) are also common pollinators, visiting flowers to feed on pollen and nectar. Some wasps will use flowers as an attractant for their insect prey, eating other pollinators. Wasp larvae vary greatly in their food sources. While some feed on plants and others are predators, many are parasitoids that develop inside the bodies of other insects. It is also common for

Figure 2.15. [left] Pollen wasps, like this male *Pseudomasaris* sp. (Vespidae), are wasps that provision their young with pollen instead of prey, often from *Penstemon* spp. [Right] Scoliid wasps (*Scolia nobilitata tricincta*) visiting milkweed flowers (*Asclepias* sp., Apocynaceae). (Photos: [l] Adrian Carper; [r] Whitney Cranshaw, Colorado State University, bugwood.org, CC BY 3.0.).

wasp adults to capture insects (either killed or paralyzed) to feed to their developing young. Some true bugs (order Hemiptera) can also act as accidental pollinators as they use flowers as hunting grounds for prey; some solitary wasps will do the same.

Bees (order Hymenoptera, superfamily Apoidea) are the most famous pollinators because the majority of them actively collect pollen as adults, which they use to feed developing larvae. Adults also feed on nectar and every bee species contributes to pollination. Bees can also access tubular flowers with their tongues, whereas other insects prefer more open or flat-faced flowers such as sunflowers, thistles, or buttercups. As a group, bees are generally understood to be the most important and effective pollinators of flowering plants. The most famous bees (including honey bees and bumble bees) are social and live together in colonies, sharing the care of offspring. These bees tend to have longer seasons during which they fly and forage on flowers. The majority of bees, however, are solitary. After mating, females create a nest, lay eggs, and provision them with pollen and nectar for the developing larvae to eat once they hatch. The majority of bees are ground nesting, so soil conditions are important for them. Cavity nesting bees require holes or openings in deadwood or dried plants to create nests.

In environments with seasonal cold weather, like Colorado, winter can be a vulnerable time for pollinating insects. Some insects require dead branches, leaves, or other plant material to overwinter. Other insects survive in the ground and are impacted by the depth of the snowpack as insulation against

Figure 2.16. A selection of Colorado bee species photographed using 2D focus-stacking macrophotography in the University of Colorado Museum of Natural History Entomology Section. (All specimens are female, unless noted.)

Left (top to bottom): *Megachile fortis*, *Megachile brevis*, *Andrena helianthi*, *Dianthidium ulkei*, *Coelioxys rufitarsis*, *Osmia integra*.

Middle (top to bottom): *Perdita kiowa*, *Hoplitis fulgida* male, *Andrena perarmata*, *Lithurgopsis apicalis*, *Chelostoma philadelphi*, *Cemolobus ipomoeae*,

Right (top to bottom): *Svastra compta*, *Megachile* sp., *Osmia lignaria* male, *Dianthidium curvatum*, *Ashmeadiella gillettei*, *Osmia ribifloris*.


3 mm

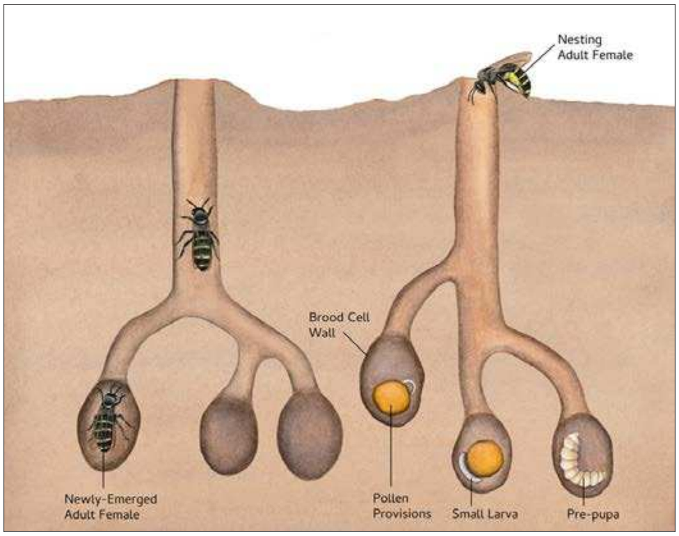


Figure 2.17. Around 60% of Colorado's bee species are ground nesting. (Adapted from Kapheim et al. 2021. [Illustration by Julie Johnson, Life Science Studios, CC BY 4.0.])

freezing temperatures. See Table 3.2 for guidance on the needs of different groups of pollinators with restoration goals aimed at supporting those groups.

2.2.3. Pollination Ecology

Pollinators vary in how specific they are in choosing which flowers they visit. On one end of the spectrum, generalist pollinators visit a great variety of flowers. Flies and beetles tend to be more generalized. On the other end of the spectrum, specialist pollinators may rely upon the flowers of one species of plant, and need the pollen from that species to feed their young. Within bees, species that forage from a variety of unrelated plants are known as polylectic, those that visit flowers from a particular plant family are called oligolectic, and those that forage on flowers from only a single plant genus or species are called monolectic. Overall, specialist pollinators are at the greatest risk from land-use change. If the plant species that they rely upon is impacted, they are also impacted. Generalist pollinators, on the other hand, because they forage from a diversity of flowers, are more resilient to environmental changes. It is important to note that plants can also specialize in the pollinators that they rely on. However, it is rare that a plant specializes in a pollinator that also specializes in that plant.

In order to understand the relationships among all of the pollinators and plants in a particular habitat, ecologists develop pollination networks. These networks consist of nodes made up of plant and pollinator species, and links between those nodes, which represent when a pollinator species pollinates a plant species. These networks are useful for understanding how species loss or disruption of pollination interactions could impact ecosystems. For example, the loss of the most generalized pollinators could have a large negative impact on the ecosystem because generalists provide pollination to many different plants.

The Colorado Striped-Sweat Bee: a Generalist Pollinator

The bright-blue Colorado striped-sweat bee (*Agapostemon coloradinus*), which is found primarily in the southern Rocky Mountains and surrounding plains, is an example of a pollinator with a generalized foraging behavior. Females visit flowers to feed and also to collect pollen, which they transport pollen to their underground nests, where it will become food for developing bee larvae. Adult females of this species forage from a variety of different flower types from at least five different plant families. This means that Colorado striped-sweat bees are able to successfully collect pollen from flowers that vary in size, shape, and color, and their larvae can eat pollen that varies in nutritional quality.

Figure 2.18. Colorado striped-sweat bee (*Agapostemon coloradinus*). (Photo: USGS BIML.)

Pollination networks that have greater average number of interactions per species involved tend to be more resilient to change.

2.2.4. Distributions of Colorado Bee & Butterflies

The CU Museum of Natural History Entomology Collection last tallied the diversity of bees within Colorado in 2011, documenting 946 different species in the state (Scott et al. 2011). As part of the current study, collections manager Virginia Scott has updated that accounting, with additional

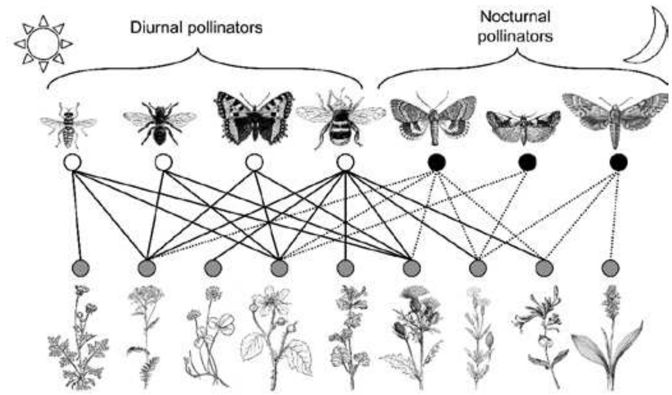


Figure 2.19. The bumble bee in the center of this example pollinator network is more generalized (pollinates more plant species) than the smallest moth, to the right, which only pollinates two plants. Generalist pollinators are a crucial part of the pollination network. (Source: Macgregor and Scott-Brown 2020, CC BY 4.0.)

The Yucca Moth: a Highly Specialist Pollinator

Yucca plants, which grow tall stalks of large white flowers in many parts of Colorado each spring, have great cultural importance to the people of the Indigenous tribes of Colorado. Yuccas also exhibit a highly specialized relationship with their pollinators, the yucca moths. Colorado is home to six species of yuccas (Asparagaceae): *Yucca glauca*, *Y. angustissima*, *Y. harrimaniae*, *Y. baccata*, *Y. neomexicana*, and *Y. baileyi*. Yuccas and their pollinators, moths in the genera Tegeticula and Parategeticula, are completely dependent upon each other; this type of relationship, with specialization of both the plant and the pollinator, is very rare in pollination.

Figure 2.20. A *Tegeticula* moth deposits pollen onto the stigma of a yucca flower. (Photo: Sherwin Carlquist, BY-SA 3.0.)

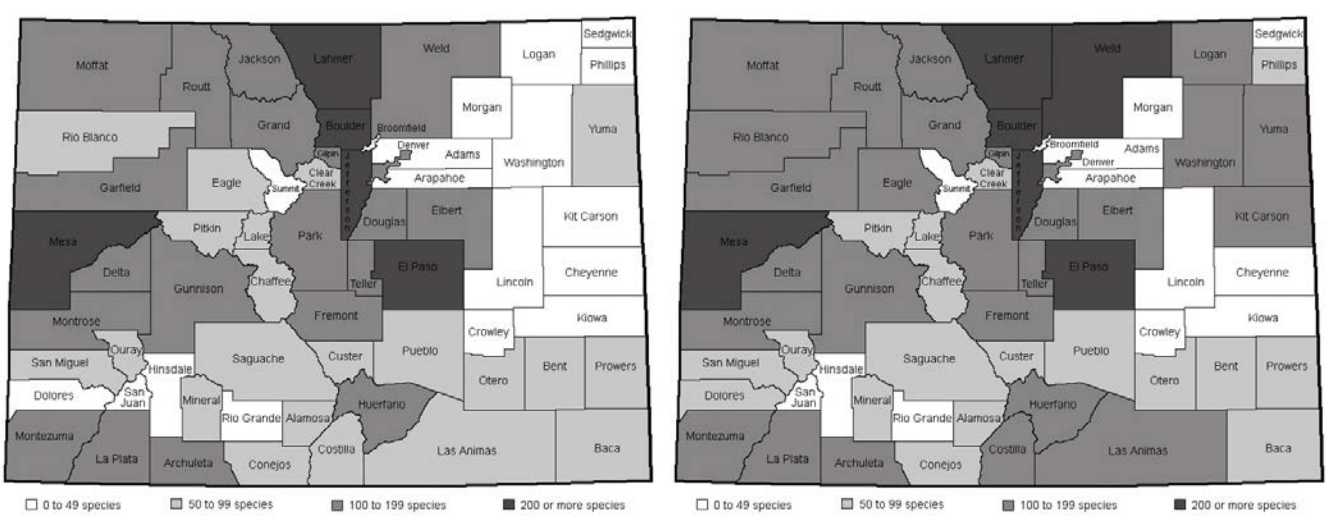
Adult female yucca moths visit yucca flowers and use specially shaped mouthparts to collect pollen from the flower anthers. They then carry this pollen to a new plant, where they search for the ideal flower. These females can identify a flower that has not yet been visited by another yucca moth. They lay a few eggs in the ovary of the flower and then place some pollen on the flower's stigma, ensuring pollination of that particular flower. Adult female yucca moths repeat this process with multiple yucca flowers. As the ovary of the yucca flower begins to develop into a fruit, the yucca moth eggs hatch inside and the caterpillars feed upon the developing fruit. The low number of caterpillars per fruit ensures that some seeds escape and mature within the fruits. Eventually, the caterpillars drop to the soil, where they pupate underground, emerging as adults in the spring in the subsequent years. This mutualistic relationship ensures that both the yucca and the yucca moth are able to successfully reproduce.

Figure 2.21. The soapweed yucca (*Yucca glauca*), which is common across the Great Plains. (Photo: Matt Lavin, CC BY SA 2.0.)

species recorded for the state, recent taxonomic revisions, and newly described species. Colorado is now home to some 1,006 bee species, distributed across 66 different genera. With ~ 20,000 species of bees in the world and 3,500 in North America north of Mexico, this means that **Colorado contains about 5% of the world's and nearly 30% of North America's bee diversity**. And this number is likely to continue to grow as researchers and managers learn more about the diversity of insects within the state. For example, there are many understudied regions within the state, including many of the most agriculturally intensive regions and more remote arid western portions. In contrast, most research has focused on high-elevation habitats or areas in close proximity to research institutions. One recent study (Jamieson et al. 2019) on the Eastern Plains of Colorado, a historically undersampled region, added 425 new county-level species occurrences and 15 new state records (species not previously known within the state) in with 9 days of surveying for native bees, with some counties producing over 15 times more species than previously known. This geographic variation in sampling for pollinators has likely limited our understanding of species distributions and how pollinators respond to human environmental impacts. For example, collections from Jamieson et al. (2019) also found six individuals of the exceedingly rare morning glory bee (*Cemolobus ipomoeae*) nearly 1,000 km from its known eastern distribution (Carper et al. 2019). This bee is a highly specialized matinal (flying in the very early morning) bee that only forages on morning glory flowers (*Ipomea purpurea*, Convolvulaceae). At the time of that publication, only 75 records of that species had ever been published, underscoring the need for more surveying in undersampled regions.

Colorado also has many native bees that are little known to managers or researchers, likely because they are so rare and narrowly distributed; many of the small species are also quite challenging to identify. The sandstone mining bee (*Perdita opuntia*), for example, known as 'the bee that works in stone' (Custer 1928), was only previously known from Colorado populations along the Front Range, where it nests in sandstone (Bennett and Breed 1985). Recently discovered specimens in Wyoming, Montana, and Nebraska (Delphia and Griswold 2021), suggest that this narrow specialist of cactus (*Opuntia* spp.) flowers may be more widespread than previously thought, but still locally rare due to the combination of its highly specific nesting and foraging requirements. Another stone-nesting species, the Pueblo digger bee (*Anthophora pueblo*), nests in the sandstone and historical pueblos at Mesa Verde National Park (Orr et al. 2016). It is similarly highly restricted geographically because of its unique adaptation to specific nesting substrates. With over

Figure 2.22. These two maps (2011 left and 2023 right), represent our rapidly changing understanding of Colorado bee diversity. Darker colored counties in 2023 represent recent additions from research in undersampled regions (e.g., Jamieson et al. 2019). Many counties, however, still have few species recorded, likely as a result of undersampling.



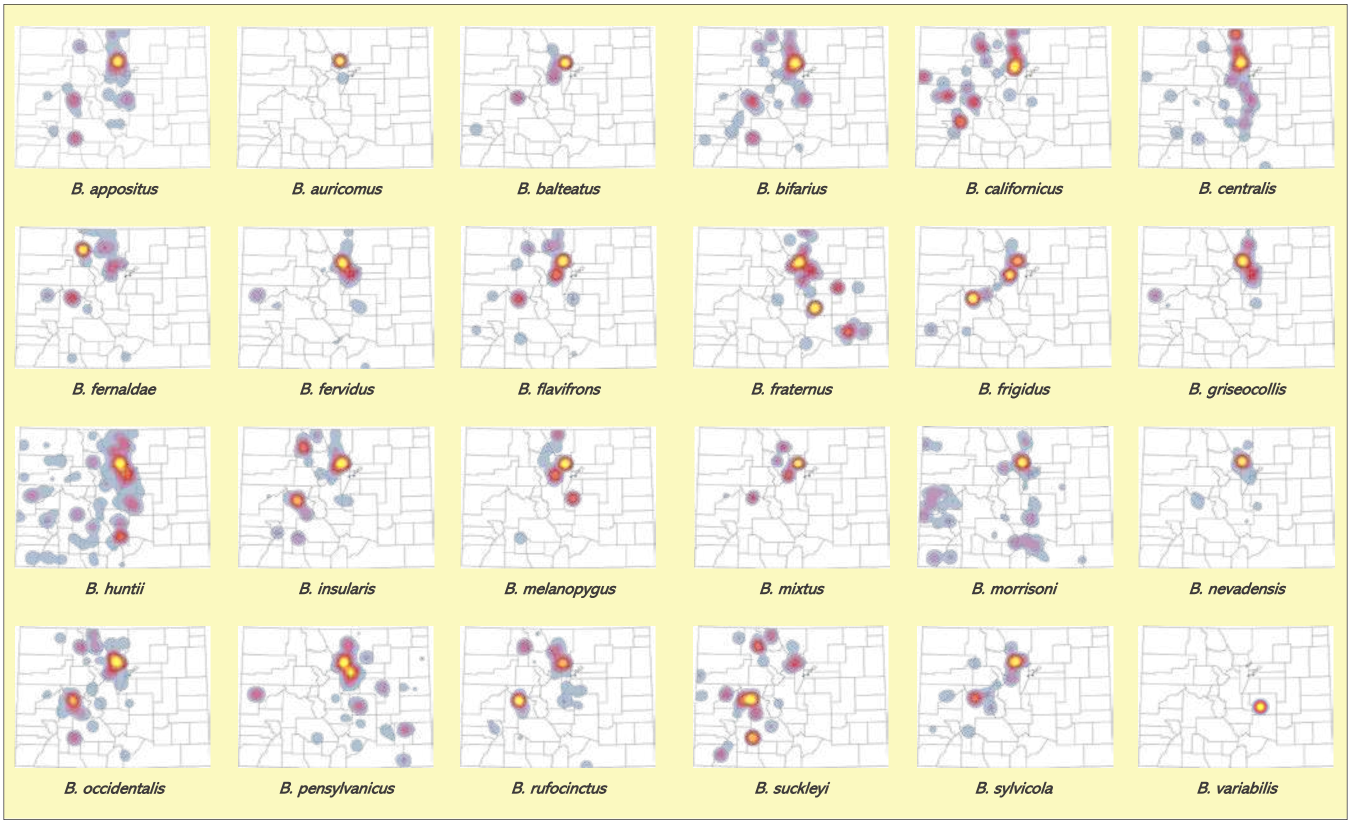


Figure 2.23. Modeled probability distributions for bumble bee species found within Colorado. Analyses were conducted by 2023 CU Denver Community-Based Practicum students Tandie Gautreau, Devin Arnold, Casey Caduff, and Antonio Luna-Galindo.

1,000 different bee species in the state, much more basic biological research is needed to understand how nesting and floral resources limit the distributions of native bees.

Bumble bees are the most studied native bees in terms of their distribution and response to human environmental change. This includes the 24 species of bumble bees within Colorado, whose distributions in the state were recently mapped by students at CU Denver (figure 2.23; also see Appendix II).

Evidence of declines in bumble bees in the United States became evident as early as 2011, with studies documenting widespread declines in bumble bee species distributions across the country. A comparative study of the distributions of bumble bees using >73,000 museum records and nationwide surveys of 16,000 contemporary specimens, showed that their ranges are contracting rapidly (over the past 20 years), likely as a result of pathogen infections from *Nosema bombi* and reduced genetic diversity (Cameron et al. 2011). *Bombus occidentalis* has declined tremendously across its range, especially along the West Coast, though appears to be somewhat protected in high-elevation areas of Colorado, compared to *B. vosnesenskii*, which has all but disappeared from Colorado while remaining along the West Coast. Other species, like *B. bifarius*, appear to be holding somewhat stable distributions (Cameron et al. 2011). Bumble bees have a diverse range of pathogens (bacteria, viruses, protozoans, nematodes, and fungi), some of which have been implicated in population declines, warranting consideration of them in both commercial and wild colonies (Evans et al. 2023; Figueroa et al. 2023). The role of commercial bumble bee production in the spread of disease to and decline of native bumble bee species has recently sparked debate about their use in greenhouse production of crops, such as tomatoes and peppers.

Colorado also has an extremely diverse butterfly community and is home to over 40% of the diversity of butterflies in North America north of Mexico. Of the 722 butterflies in North America north of Mexico (NABA), the Butterflies and Moths of North America (BAMONA) checklist for Colorado records 294 species within the state. While not known to be the most effective pollinators, the work of James Scott, who over a period of more than five decades (1959–2013) compiled over 40,000 records of adult butterflies' feeding preferences in Colorado, shows that butterflies visit and likely contribute in some degree to the pollination of hundreds of species of native plants in the state (Scott 2013). Butterfly communities along the Front Range vary by habitat type and through time, being particularly abundant along riparian areas of the plains and foothills (Robinson et al. 2012). However, little research has been done exploring how butterfly communities have changed through time in Colorado or what mechanisms structure their communities. An ongoing re-survey at the Rocky Mountain Biological Laboratory will soon provide some information about changes since the 1980s. Work in other areas has shown that butterflies are moving up in elevation and latitude, probably in response to the changing climate (e.g., Forister et al. 2010).

2.3. Research on Pollinators (History & Major Projects)

2.3.1. Major Institutions

Colorado is home to a thriving community of pollination researchers whose work builds upon a rich history of research on native pollinating insects in the state. Researchers at several institutions have been studying pollinators for over a century, resulting in a substantial body of knowledge on the distribution, diversity, ecology, and evolution of the state's pollinators. Researchers from around the globe have come to Colorado to study pollinators, drawn by the great variety of pollinating insects and their importance to the flowers found here, as well as Colorado's large protected natural areas. Historically, most pollinator research in Colorado focused on the taxonomy of insects and basic biological questions about insect species and their interactions with plants. Within the past decade, however, many researchers have begun to ask applied questions, such as how land management impacts pollinators and how land managers could potentially mitigate negative impacts. Here, we briefly outline the major research institutions within Colorado that have contributed to our understanding of pollinators. These institutions are valuable resources for our state agencies as repositories of knowledge, and as potential sources for future cooperation or collaboration on management-driven research on native pollinating insects.

The C. P. Gillette Museum of Arthropod Diversity (at Colorado State University, agsci.colostate.edu/agbio/gillette-museum/), is the oldest institution in the state that focuses on the study of insects. Founded in 1870, the Gillette Museum has **Colorado's largest collection of arthropods** (a group of animals which includes insects as well as spiders, crustaceans, and others), **totaling 4.7 million specimens** as of December 2022. **Museum collections of insects protect a wealth of information about pollination.** Each insect in the collection has a record of the date, location of collection, habitat type, and whether it was found on a particular plant species. This information can, for example, reveal changes in where pollinator species have been found over the last century and a half. The insects themselves can also be used by current researchers to confirm species identifications and investigate evolution through comparisons of historic and modern specimens.

The Gillette Museum's insect collection focuses on the Rocky Mountain region and serves as a repository for 23 National Park sites, including Rocky Mountain National Park, Mesa Verde National Park, and Colorado National Monument. The museum also holds the Center for Disease Control's mosquito collection. The Gillette Museum collection includes many key groups of pollinating insects, especially lesser known groups. Of note are the museum's flies (including pollinators such as flower flies and mosquitoes), wasps (especially wasps of the western United States, collected by renowned hymenopterist Howard Ensign Evans), and Lepidoptera (including butterflies, sphinx moths, and clearwing moths). The museum's butterfly specimens alone number 74,000. The museum also holds many scarab beetles and long-horn beetles, which are common but often-overlooked pollinators. The museum is currently working to digitize bee records into SCAN, the Symbiota Collections of Arthropods Network (scan-bugs.org/portal/), through the NSF-funded iDigBees Thematic Collections Network. Already, 23,000 records have been digitized, with 78,000 more to be completed over the next three and a half years. Digital records include high-quality images of specimens (such as the butterfly and bee specimens shown in figures 2.10 and 2.16, respectively) as well as written information. Digitization makes it easy for anyone (from out-of-state researchers to members of the public) to access and utilize these important records.

Colorado State University's Forest and Rangeland Stewardship Department includes two labs currently studying pollinators and their role in Colorado's ecosystems. Seth Davis' Forest Health Lab (people.warnercnr.colostate.edu/?thomas.davis) is researching insect ecology in forest and agricultural habitats, with recent research focusing on how forest management affects the flowers that bumble bees rely on. One researcher in the lab, Jessie Dodge, is currently studying the orchard mason bee (*Osmia lignaria*), a solitary native bee. Headed by John Mola, the

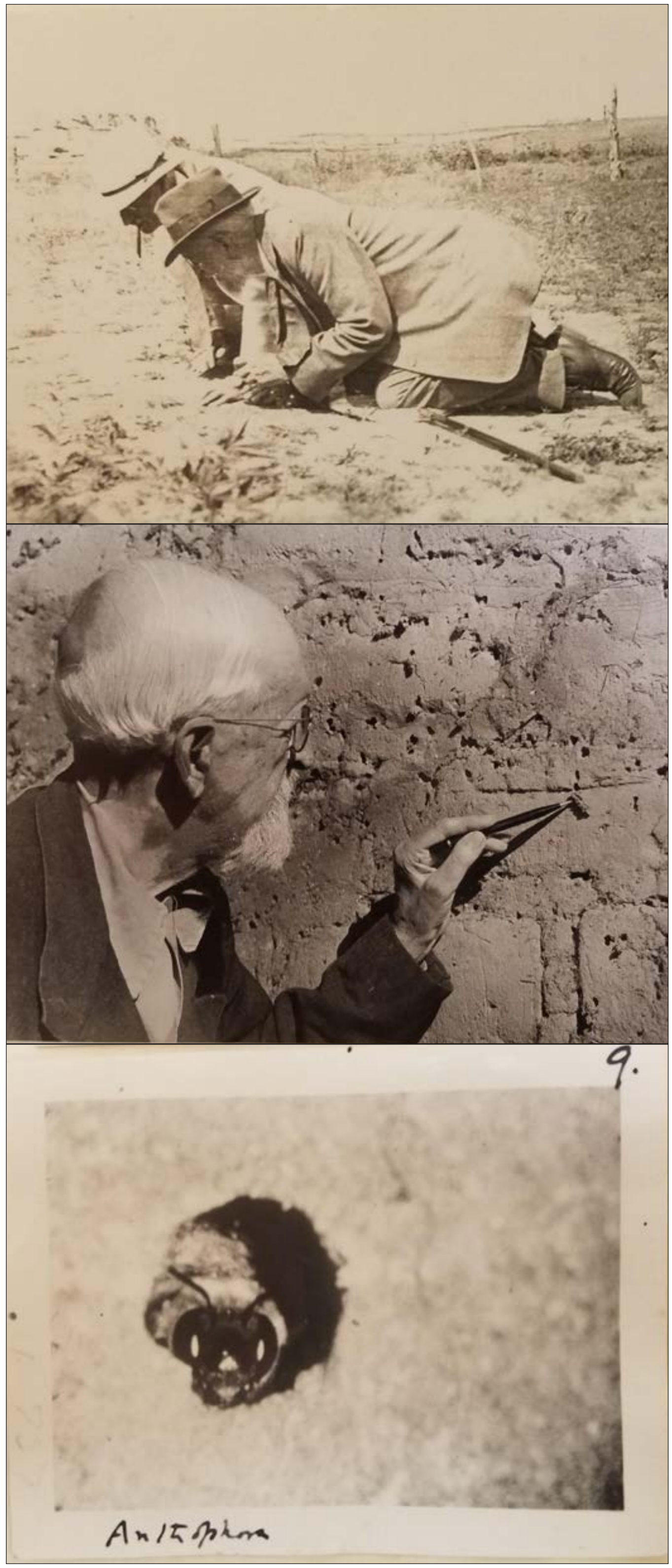


Figure 2.24. Researchers have studied pollinators in Colorado for over a century. Photos archived in the T.D.A Cockerell Collection at the University of Colorado Boulder Libraries Special Collections, Archives, and Preservation show Cockerell (top and center) inspecting a ground nesting aggregation of bees or wasps circa the 1930s, and photographing a digger bee, *Anthophora* (bottom).

Mola Lab (molalab.org/) is researching the ecology of pollinators (especially bees) in urban and forest habitats, with a special focus given to conservation of endangered pollinators such as the western bumble bee (*Bombus occidentalis*).

The University of Colorado Museum of Natural History (CUMNH), founded in 1902, constitutes the largest natural history collection in the Rocky Mountain region. The CUMNH Entomology Collection (www.colorado.edu/cumuseum/research-collections/entomology), which has done extensive research on pollinating insects, houses approximately 1.1 million insect specimens, and is the largest collection in the museum. Pollinators such as butterflies, beetles, and flies are well represented, but the real strength of the CUMNH Entomology Collection lies in its bees. **Roughly 170,000 bee specimens, most native to Colorado, can be found in the museum's cabinets, the largest collection of bees in Colorado.** This is primarily a result of research collections by taxonomists within the CUMNH Entomology Section, which has been home to bee researchers for nearly all of its 121-year history. Famed naturalist Theodore Dru Alison Cockerell, who described over 6,400 species and subspecies of bees in his lifetime, helped start the museum and remained a curator there until 1934. Hymenopterist Hugo Rodeck (who studied bees, wasps, and ants) served as the director of CUMNH from 1939 to 1971. Url Lanham, Curator of the Entomology Collection from 1961 to 1989, also focused on bees, especially the solitary bee genus *Andrena*. Virginia Scott, CUMNH Collections Manager of Entomology since 1994, specializes in native bees and compiled the current list of known bees in Colorado (Scott et al. 2011). Additionally, the Entomology Collection's most recent curator, M. Deane Bowers, studied butterflies and helped build the collection's current holdings of 70,000 butterflies and moths. Research Associate Adrian Carper has also vouchered over 75,000 specimens, mostly native bees, from a number of research projects within Colorado since 2013. The CUMNH Entomology Collection is currently photographing and digitizing its collection of bees as a part of the Big-Bee Thematic Collections Network (library.big-bee.net/portal/). From 2013 to 2016, the Entomology Collection ran a participatory science project called The Bees' Needs (beesneeds.colorado.edu/), which investigated the nesting behavior of solitary cavity-nesting bees across the Front Range Urban Corridor of Colorado.

Colorado has also been home to ecological field research on pollinating insects for nearly a hundred years, especially in its ecologically fascinating mountain regions. Founded in 1928 amid the ruins of an old silver mining town just outside of Crested Butte, the Rocky Mountain Biological Laboratory (RMBL) is now a hub for long-term field research on pollination, climate change, and high-altitude ecosystems. **Since the 1970s, researchers at RMBL have been studying local pollinators, resulting in valuable long-term data on the ecology of pollinators in the mountains of Colorado.** Though most researchers who work at RMBL are based out of institutions in other states, their work at RMBL has contributed tremendously to knowledge of Colorado pollinators. Researchers such as David Inouye (emeritus at the University of Maryland), Nick Waser and Mary Price (both emeritus at the University of California–Riverside), the late Bill Calder of University of Arizona, Diane Campbell of the University of California–Irvine, Rebecca Irwin of North Carolina State University, James Thomson (emeritus at the University of Toronto), and Berry Brosi of the University of Washington are globally renowned for their contributions to the fields of plant and pollinator ecology and evolution.

Many more researchers have also now developed rigorous research programs there. Publications from work done at RMBL have mostly focused on bumble bees, solitary bees, butterflies, and hummingbirds, but have also investigated moths, flies, and mosquitoes. Long-term field research is extremely valuable for revealing patterns that can be obscured by yearly fluctuations. There are several ongoing long-term monitoring projects at RMBL. One study, which was started in 1973, tracks the phenology and abundance of flowers in the area (CaraDonna et al. 2014). Another project has been recording the abundance and diversity of insects at RMBL every year since 1986 and documenting a major decline (Dalton et al 2023). A newer effort surveys the abundance and emergence time of bees at different elevations and began in 2009 (Stemkovski et al. 2020), and another is re-surveying butterflies for comparison with 1980s data. Hummingbirds have also been surveyed for 50 years at RMBL; the oldest known hummingbird in the wild (a female broad-tailed hummingbird who was at least 13 years old) is a record from RMBL.

As concern for pollinator health grows, researchers at other academic institutions in Colorado are also starting to tackle projects focused on pollinating insects. The CU Denver Bee Project, headed by Christy Briles, is currently studying the effects of urban habitat on native bees and honey bees. A recent master's thesis by Kristen Birdshire, a student at CU Denver, looked at the factors impacting bee communities in the Denver metro area. Additionally, CU Denver graduate students in several courses are using geospatial techniques to map pollinator distributions, resources, and populations. While University of Denver scientist Shannon Murphy is primarily concerned with plant–herbivore interactions, some of her lab's recent work focuses on pollinating insects. Master's student Alaina Smith is studying the effects of wildfire severity on solitary cavity-nesting bees and wasps. In collaboration with Julie Morris and graduate student Eva Horna Lowell, the Murphy Lab is also studying honey bee behavior and how to utilize honey bees to increase non-STEM undergraduate students' interest in STEM topics.

Some researchers have also specifically studied imperiled butterflies in Colorado. The Colorado Natural Heritage Program at CSU has researched the Pawnee montane skipper (*Hesperia leonardus montana*) and inventoried other rare butterflies in Colorado. Dr. Kevin Alexander and his lab at Western Colorado University have monitored the endangered Uncompahgre fritillary (*Clossiana improba acrocnema*) in the San Juan Mountains and researched the habitat of this species in order to understand its very specific environmental requirements.

While the vast majority of the Denver Botanic Garden's collections—live and otherwise—are plants, **the Gardens have a small arthropod collection, founded in 2015, that houses many local pollinating insect**s. The Garden uses these arthropods to educate the public about the role of arthropods, including pollinators, within the Gardens and in Colorado's wildlands. Most of the arthropod collection's 4,400 specimens were bees deposited by CU Boulder Master's student Liam Cullinane as a part of his 2015 thesis on bee abundance and diversity in the Denver area. Plant collections can also be utilized to understand changes in the abundance, diversity, and timing of flowering plants that pollinators depend on.

These scientific institutions collectively hold a wealth of resources, both in physical insect specimens, information about Colorado pollinators, and scientific expertise. With impressive insect collections at natural history museums, long-term ecological field research, and current research studies on the impacts of urbanization and land management, Colorado has a strong scientific foundation for future efforts aimed at pollinator conservation.

2.3.2. Factors Impacting Pollinator Communities

Many factors negatively impact pollinating insect health and the majority of research in Colorado has focused on identifying what and how different factors affect pollinator abundance, diversity, and relationships with plants. **Land-use change is the permanent conversion of natural habitats to human-dominated land use** such as agricultural and urban landscapes—and is the biggest driver of habitat loss and pollinator decline globally (Millard et al. 2021) and within Colorado. Natural lands in the United States, which are likely to have a long history of management by Indigenous peoples, have not experienced the dramatic ecological changes, including sharp declines in biodiversity and alterations of the physical landscape, that human-dominated lands have experienced since Euro-American settlement. The factors that determine how and to what degree land-use change impacts pollinators are complex, but **untangling this complexity can allow researchers to determine the impacts of specific factors on different groups of pollinators and in different land-use contexts. This may be the key to developing land management strategies that can minimize the negative effects of land-use change on pollinators.** For example, while monoculture cereal crops offer few resources for our diverse pollinators, by incorporating flowering crops into their rotations or planting diverse conservation set-asides in marginal land, land managers can mitigate some of the negative impacts of the lost natural habitat. Similarly, while overgrazing by cattle could lead to highly degraded rangeland and negatively impact pollinators that persist there, those same habitats could be restored using more holistic grazing practices to promote more diverse native plant communities. Thus, while the legacy of land-use change is the biggest threat to Colorado's pollinators, how we manage land is our most powerful tool in their conservation and human land use may very well represent our biggest opportunity to have positive impacts.

In addition to habitat loss, **climate change and pesticides represent existential threats to pollinators**, and have been well established as serious drivers of the declines of global pollinating insects. Moreover, climate change can interact with other drivers such as land-use change, to compound its negative effects. Most research in Colorado and around the world focuses on how these mechanisms impact pollinators. However, a growing need to understand how management can mitigate their impacts is now spurring new interest in applied research, especially studies that apply ecological or conservation theory to relevant management questions. In *New Research and BMPs in Natural Areas: A Synthesis of the Pollinator Management Symposium from the 44th Natural Areas Conference, October 2017*, researchers highlighted the dire need to begin to incorporate the grazing, forest management, and habitat restoration into the development of new best management practices for native pollinators and stressed the need for management strategies that can adapt as new research on pollinators emerges (Wojcik et al. 2018). In this section, we review what is known about the primary drivers of native pollinating insect abundance and diversity within Colorado, and how this and other studies could impact the development of management or conservation strategies aimed at native pollinating insects.

2.3.3. Agricultural Croplands

Takeaways:

- Historic and continued conversion of land to agricultural use represents the largest source of habitat loss for pollinating insects globally and in Colorado.
- Better management of agricultural land can mitigate some of the impacts of habitat loss.
- Many crops provide few resources for native pollinating insects.
- Diversifying crops or habitats within agricultural landscapes can promote pollinator health.
- More research is needed on how to benefit both agriculture and native pollinators.

Agricultural land use is the largest factor driving the permanent loss of natural habitats worldwide.

The vast majority of arable land was historically prairies, savannahs, and grasslands, and global predictions suggest that future agricultural expansion will further reduce habitat for the vast majority of species (Williams et al. 2021). Moreover, as the need to feed a growing human populace continues, cropland is continuing to expand in the United States. Over the past decades, places not historically cultivated for crops, like Colorado's northwestern counties, have been increasingly cultivated (Lark et al. 2015). With some 38,800 farms operating on 31.8 million acres (USDA/NASS 2023a), nearly 50% of the area of Colorado (66.6 million acres) is currently used for agricultural purposes. This includes more than 11 million acres of cropland, so roughly 16% of the state has been converted to cropland. According to the most recently released USDA Census of Agriculture, croplands increased by approximately 400,000 acres in Colorado between 2012 and 2017 (USDA/NASS 2023f).

In this section, we focus specifically on lands used to cultivate crops. We discuss rangelands that are used for livestock grazing, another important part of Colorado's agricultural economy, in Section 2.3.5 Grazing and Rangeland Management below. Agriculture is no doubt an extremely important component of Colorado's economy, culture, and human well-being. There is, however, substantial evidence of the negative impacts that agriculture-driven habitat loss and some agricultural practices have on pollinators. There also is substantial evidence of the value of restoration and conservation activities *within* agricultural landscapes that benefit pollinating insects. Thus, while the permanent conversion of natural habitat to agricultural land use is arguably a human necessity, **how we manage that agricultural land can indeed mitigate some of the impacts of its associated habitat loss**.

The conversion of natural lands into croplands replaces diverse communities of native plants with markedly less diverse fields of domesticated crop plants. Both the shift in plant species and the loss of plant diversity have dramatic impacts upon pollinators, which rely on plants for nectar and pollen, and as host plants for larval development. The most agriculturally intensive croplands do not provide the resources necessary for pollinators, although management strategies that increase the diversity of plants in agricultural settings, particularly the diversity of flowering plants that provide nectar and high-quality pollen to pollinating insects, can help to support pollinators within these altered landscapes.

Some crop plants do provide floral resources that can be utilized by pollinators. For example, several agricultural crops within Colorado, from hemp (O'Brien and Arathi 2019) to cantaloupe (Adamson et al 2012), provide pollen and nectar resources that could benefit the native pollinating insects that use them. The squash bee (*Eucera pruinosa*), for instance, is a rare example of a specialist pollinator that has expanded its native range by following the expansion of cucurbit crops, such as melons, squash, and pumpkins, and has even evolved to specialize on those human cultivated crops (Pope et al. 2023). **Intermixing**

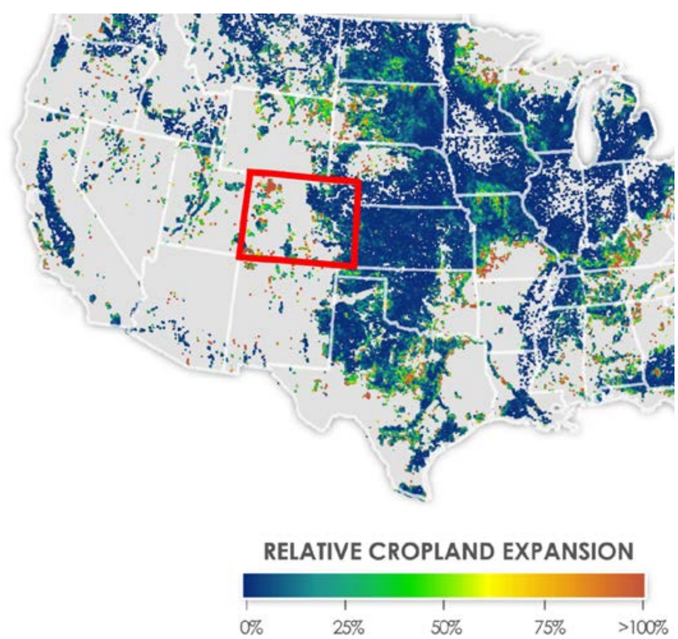


Figure 2.25. Map represents the amount of new cropland expansion relative to cropland extent in 2008. Areas in red are hotspots where the amount of cropland more than doubled between 2008 and 2012. Mapping relative expansion illuminates the "new frontiers" of agriculture, or locations where cultivation is rapidly encroaching into areas previously reserved for other uses. (Adapted from Lark et al. 2015.)

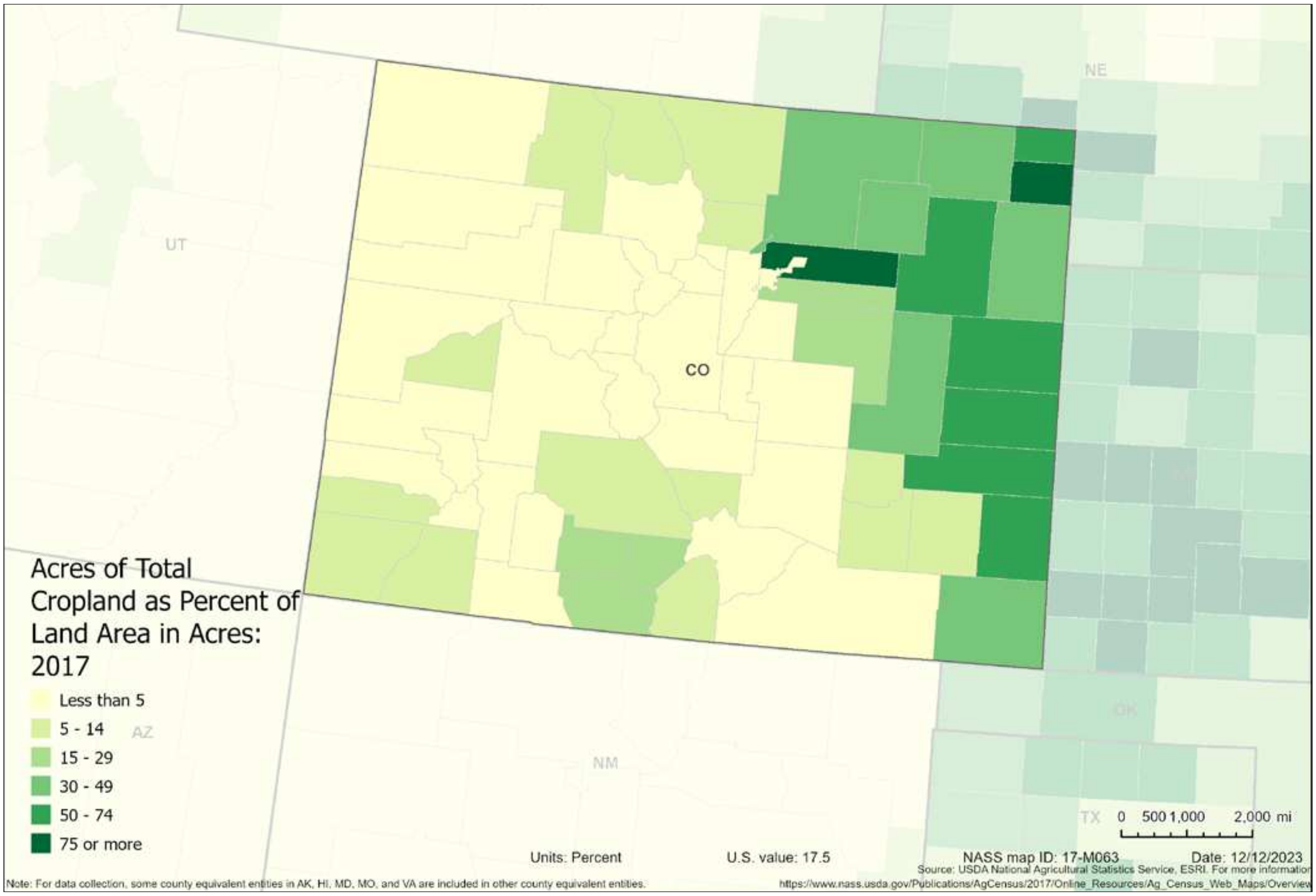


Figure 2.26. In Colorado, croplands are most common on the Eastern Plains, where most counties are at least 30% cropland. (Source: USDA/NASS 2017.)

crops that do provide floral resources with those that do not could help promote pollinators and does not necessarily have to impact production. However, the majority of native bee species cannot subsist on a single host plant species, even if that species provides valuable floral resources. So intermixing strategies that present the greatest source of floral diversity should be the most beneficial to bees in agricultural fields. For example, by cover cropping with diverse forb mixes (made up of wildflowers), fallow fields in dryland wheat farms in northeastern Colorado can still support a diverse community of native bees (O'Brien and Arathi 2021). What constraints there are to the adoption of practices that could better provide floral resources within cropped land in Colorado is little studied though.

Most of Colorado's cropland is covered by wind-pollinated cereal crops, which provide less value to bees than most insect-pollinated flowering plants. Wind-pollinated plants do not produce nectar and their pollen is generally less valuable for pollinators, being less protein-rich and overall less nutritious for pollinators (Roulston and Cane 2002). In one large study covering five of the most agriculturally intensive counties in northeastern Colorado, researchers found that the amount of grassland habitat and wind-pollinated crops drove dissimilarity between bee communities, with different types of bees responding to agricultural land use and grasslands at different scales, depending on body size (Schwantes 2015). For example, larger bees that can fly farther to find patches of flowers were less impacted by agriculture than smaller bees which are more restricted and thus more susceptible to habitat loss. In addition to intermixed semi-natural grasslands, field margins and roadside edges of wild-pollinated crop fields often had much more diverse plant communities, with abundant native flowers, especially prairie sunflower (*Helianthus* *petiolaris*, Asteraceae), an important late-season host plant for large-bodied native sunflower-specialist bees. Schwantes (2015) found that within this agricultural region, the abundance of large bees increased with increasing amounts of roadside-edge habitat, likely driven by the availability of sunflowers in particular. In contrast, small bees were negatively impacted by increasing roadside edge, likely because fewer small bee species can utilize sunflower pollen (Schwantes 2015). Research from outside of Colorado suggests that increased flowering plant diversity in field margins could also support butterflies (Ouin and Burel 2002) and syrphid flies (Haenke et al. 2009). Thus, managing a diversity of non-cultivated land, including grasslands and roadside edges, within agriculturally intensive regions, could be a valuable opportunity to create beneficial pollinator habitat for a variety of pollinators, regardless of the types of crops grown in the region.

While more cropland likely won't provide more resources for pollinators, **how farmers manage marginal land**, such as field edges, corners, or less-productive parcels, **could have positive impacts on pollinating insect communities**. For instance, increasing the abundance and diversity of flowers in surrounding non-crop habitats for pollinators or setting aside marginal land to create pollinator habitat, can promote abundant and diverse pollinating insect communities. Studies in California have demonstrated that the establishment of perennial habitats in intensive agricultural landscapes can promote the establishment and persistence of diverse and abundant pollinator communities (M'Gonigle et al. 2015). In Colorado, USDA Farm Bill conservation programs such as the Environmental Quality Incentives Program (EQIP), the Conservation Stewardship Program (CSP), and the Conservation Reserve Program (CRP), have long compensated farmers for removing marginally productive land from cropping. Such areas are planted with perennial grasses, forbs, or shrubs for multiple beneficial conservation goals, from soil conservation

Figure 2.27. A student at the University of Colorado Boulder photographs native bees on wildflower plantings to promote native pollinators on Red Wagon Organic Farm. (Photo Adrian Carper.)

Figure 2.28 Top: Many Coloradans may not recognize the agriculturally intensive Eastern Plains, viewed here with Google satellite imagery (top). Green circles are primarily center-pivot irrigated corn fields. Tan, brown, and yellow rectangles are a mix of cereal and other crops (shown in the lower left image). Yet even in this landscape, irregular patches of light green grasslands and parcels of land enrolled in the Conservation Reserve Program (like the pollinator habitat created under the CP42 practice shown on the lower right) provide important areas for pollinators. Expanding and connecting these patches could help improve their conservation value. (Photos: Adrian Carper.)

to wildlife habitat creation. One assessment of the value of diversified CRP plantings measured bee communities in CRP lands planted with grass mixes compared to a wildflower mix designed for pollinators. After three years, the wildflower-mix plantings had more bees and more variety of bee species (greater abundance and diversity) than grassland plantings, suggesting that diversified conservation plantings can promote more diverse pollinating insect communities (Arathi et al. 2019). CRP lands can also promote healthier pollinator populations. For example, Morphew (2017) compared CRP fields to native rangeland for cavity-nesting bees by measuring bee abundance, diversity, and reproduction. They found that CRP plantings supported twice the abundance of cavity-nesting bees, and as many native bee species as native rangelands; moreover, bee diversity and reproductive capacity, regardless of habitat type, were positively related to the diversity of flowers within sites (Morphew 2017). These studies suggest that conservation set-asides serve as important refuges for native pollinating insects, and that increasing the diversity of floral resources within them is likely an effective way to help conserve insect pollinators within the most agriculturally intensive regions of Colorado. More research on how best to diversify these areas, in terms of both plants and pollinators, how to connect them across landscapes, and how to encourage adoption of such practices could help mitigate the worst effects of agriculture-driven habitat loss.

Given that *agriculturally intensive* practices such as monoculture row cropping cannot support diverse insect pollinator communities, in some regions farmers are exploring more *ecologically intensive* agricultural practices. Ecologically intensive agriculture focuses on practices that encourage sustainable ecosystem services and natural ecological processes, such as building healthy soils, natural pest control, and resilient pollinator communities. In one global review of ecologically intensive farming practices, researchers found that practices that promoted pollinators, healthy soil biota, and other biodiversity most beneficial to agricultural crops, also partially mitigated habitat-loss-driven pollinator declines by providing more nesting and foraging resources (Kovács-Hostyánszki et al. 2017). This review suggested that policies and practices to increase ecologically intensive farming practices could play a large role in conserving pollinators while creating more sustainable agricultural systems. Although these practices can be found on smaller farms throughout Colorado, the scalability of such practices likely depends on access to training, resources, and motivation to adopt more ecologically intensive farming practices, as well as market-driven economic choices faced by farmers and trade-offs in scalability. To our knowledge, no research has been published from Colorado on the adoption of more ecological farming practices.

2.3.4. Urbanization

Takeaways:

- Urbanization is the second biggest driver of habitat loss worldwide.
- Pollinators generally decline with increasing urban development.
- Floral and nest resources are the most limiting factors for urban pollinators.
- Parks and corridors in urban areas can promote native pollinator communities.
- Light pollution negatively impacts pollinating insects.

Urbanization, the process through which rural landscapes are permanently converted to suburban and urban areas, is the second largest driver of habitat loss worldwide, impacting both biodiversity and ecosystem processes (Seto et al. 2012). Urbanization reduces the diversity of pollinators when compared to surrounding natural habitats (Wenzel et al. 2020), with strong negative effects on early season, solitary, specialist, and ground-nesting bees, in addition to butterflies and moths (Liang et al. 2023). These negative effects are driven primarily by increasing the amount of human-made surfaces (also called impervious surfaces), such as roofs, parking lots, roads, and driveways, that reduce natural and herbaceous habitat overall. Urban areas also lack other habitats, such as bare ground, which are important nesting habitats for ground-nesting pollinators. Like agriculture, the development of housing is a human necessity and rates of housing development have important impacts on socioeconomic conditions in the state. Consideration of the impacts of this type of habitat loss upon pollinators, however, can inform the way that development proceeds and support the use of strategies to minimize the impact of urbanization upon Colorado's pollinating insects.

In Colorado, **a growing human population is driving a rapid expansion of urban and suburban development**. For example, the Denver Metro Area more than tripled in size between 1950 and 2000, converting prairie and agricultural land to residential and business communities (USGS 2021). Even within Denver's urban areas, the increasing intensity of urban development in the city from 2007 to 2018 led to decreases in grass, tree, and agricultural land cover, and concurrent increases in developed areas and roads (Gutierrez Garzon et al. 2022). This urban development exacerbated habitat loss in areas that historically offered limited foraging and nesting habitats for native pollinating insects.

How pollinating insect communities respond to urbanization depends on how urban development impacts nesting and floral resources, which vary geographically. For instance, globally, cities experiencing urban sprawl (a moderate level of urbanization, also known as suburban, which often includes many greenspaces) can exhibit increased pollinator diversity compared to intensive, often monoculture agricultural lands (Wenzel et al. 2020). Few comparisons, however, are available for the effects of urbanization relative to diversified agricultural systems. In Denver, Colorado's largest urban area, several research projects have sought to quantify the impacts of urbanization on native pollinating insects. In a comparison of native bee communities in rural, suburban, and urban areas across the Denver Metro Area, Birdshire et al. (2020) found that all types of wild bees declined in abundance and diversity with increasing urbanization. However, medium- and large-bodied, hive-nesting, and social bee species, like bumble bees, were all positively associated with increasing floral richness (Birdshire et al. 2020). These results suggest that increasing flower diversity in urban areas could help ameliorate the negative effects of urbanization on bees.

In the Front Range, pollinators show **both species- and guild-specific responses to habitat change due to urbanization**. Guilds within the pollinator community are composed of groups of species that use shared resources even if in different ways. For example, ground-nesting bees all nest in soil while cavity-nesting bees use holes in dead wood or hollow stems. These different nesting guilds are all pollinators but also depend upon the distribution of different nesting resources in the landscape. Similarly, different sizes of bees utilize resources at different spatial scales, as small bees cannot fly as far as large bees in search of nesting and floral resources. In one study of suburban bee communities across the Front Range, the effects of urbanization depended on the amount of natural habitat in the landscape across different spatial scales. Small areas of native grassland surrounded by sprawl supported different bee guilds and species than larger remnant habitats (Hinners et al. 2012). Another study in Denver found contrasting effects of urbanization on bees depending on how they nested: more negative impacts of urbanization on ground-nesting bee species, but positive impacts on wood- and cavity-nesting species (Cullinane 2020).

One factor that may be driving diverse pollinator responses is the abundance of non-native plants in urban areas. For example, generalist bees are often more abundant than specialists in suburban areas, which can have abundant and diverse floral resources but are typically dominated by non-native plants. One study along the Front Range found that 45% of pollen collected from the bodies of foraging native bees was from non-native plant species (predominantly *Convolvulus arvensis* [Convolvulaceae], *Melilotus alba* and *M. officinalis* [Fabaceae]; *Carduus nutans* [Asteraceae]; and *Elaeagnus angustifolia* [Elaeagnaceae]) (Hinners and Hjelmroos-Koski 2009). This study was dominated by generalist bee species, which are more resilient to changes in flowering-plant communities. For more specialized bees, which require pollen from specific species to feed to their larvae, non-native plant abundance in developed environments is likely a limiting factor. For example, in Denver, Cullinane (2020) found that native bee abundance was negatively related to urbanization and positively to floral abundance, and that more native bees were found on native plant species.

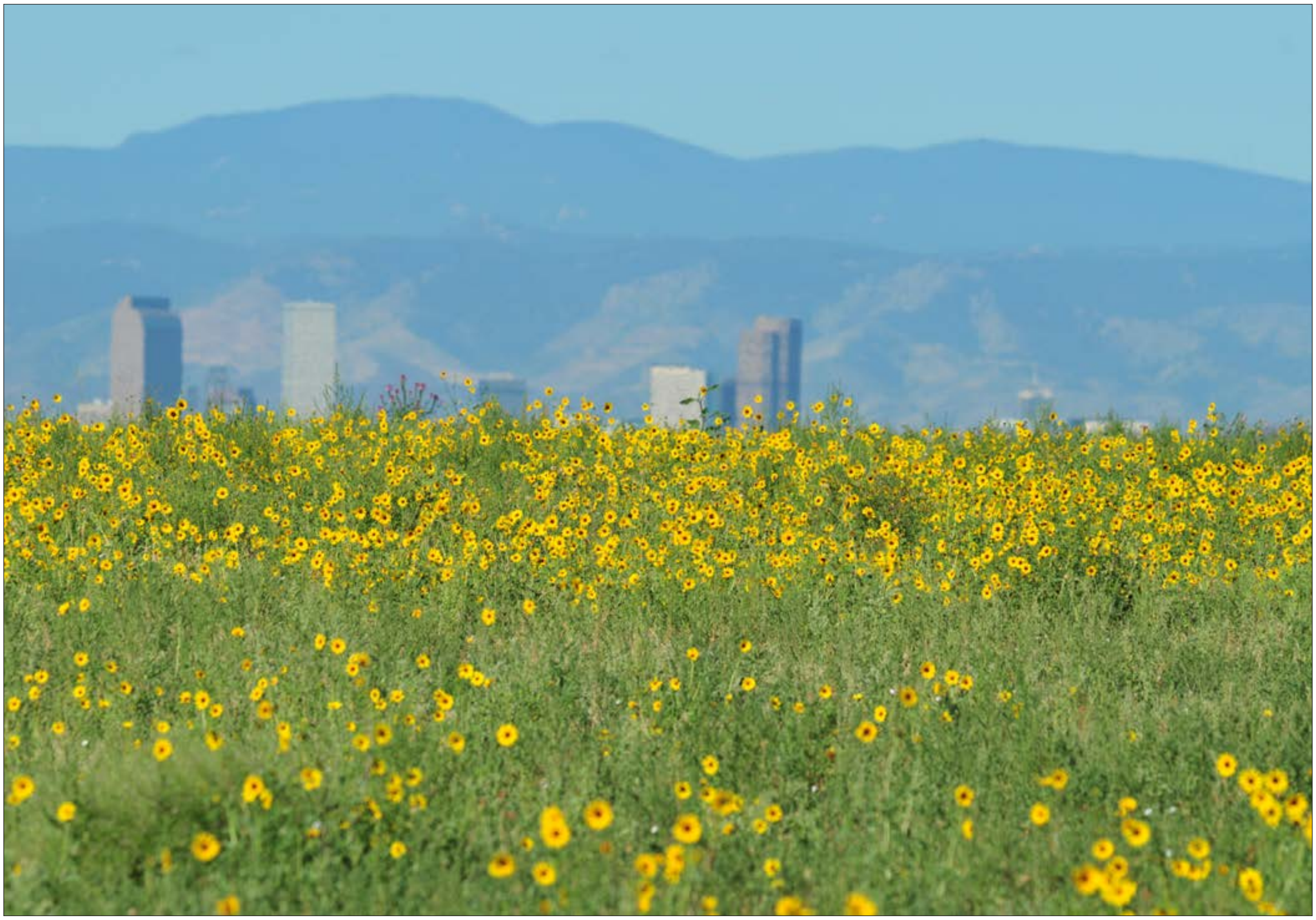


Figure 2.29. Flowers at the Rocky Mountain Arsenal National Wildlife Refuge, which is embedded in an increasingly urban landscape. (Photo: by USFWS Mountain-Prairie, CC BY 2.0.)

In addition to habitat loss, u**rbanization also results in fragmentation of natural habitats** that can have lasting impacts on native pollinating insects. The fragmentation of natural habitats into smaller and more isolated patches makes foraging and nesting resources harder to find for small pollinating insects. Protected parks and greenspaces, which can serve as reservoirs of native biodiversity in cities therefore could benefit from being more connected to each other and to natural habitats and to restored areas in urban habitats. Even urban parks and trails across Denver can host fairly diverse bee communities (Kwasniewski 2023). A study of bees along the High Line Canal Trail across Denver (Figure 2. 30) found evidence that it could be an important habitat corridor for pollinators. The High Line Canal corridor had abundant and diverse bee communities, and even supported higher elevation species, such as *Hoplitis fulgida*, which likely dispersed along the woody riparian corridor (Cullinane 2020). In a study of butterflies in the Denver Metro Area, butterflies were more abundant in larger natural habitats and in sites with increasing water availability (Robinson 2014), likely reflecting the importance of scale and connectivity in supporting the value of natural habitat patches.

The impacts of urbanization can also interact with other drivers of environmental change. For example, urban environments often magnify the effects of anthropogenic climate change. As the climate warms, there are associated increases in the risk of catastrophic weather, like rain and flooding events. Following an extreme rain event in 2013 (see Section 2.3.9 Climate Change), Longmont experienced severe flooding, especially across the urban reaches of the St. Vrain Creek. Surveys of native bees before and after the flood

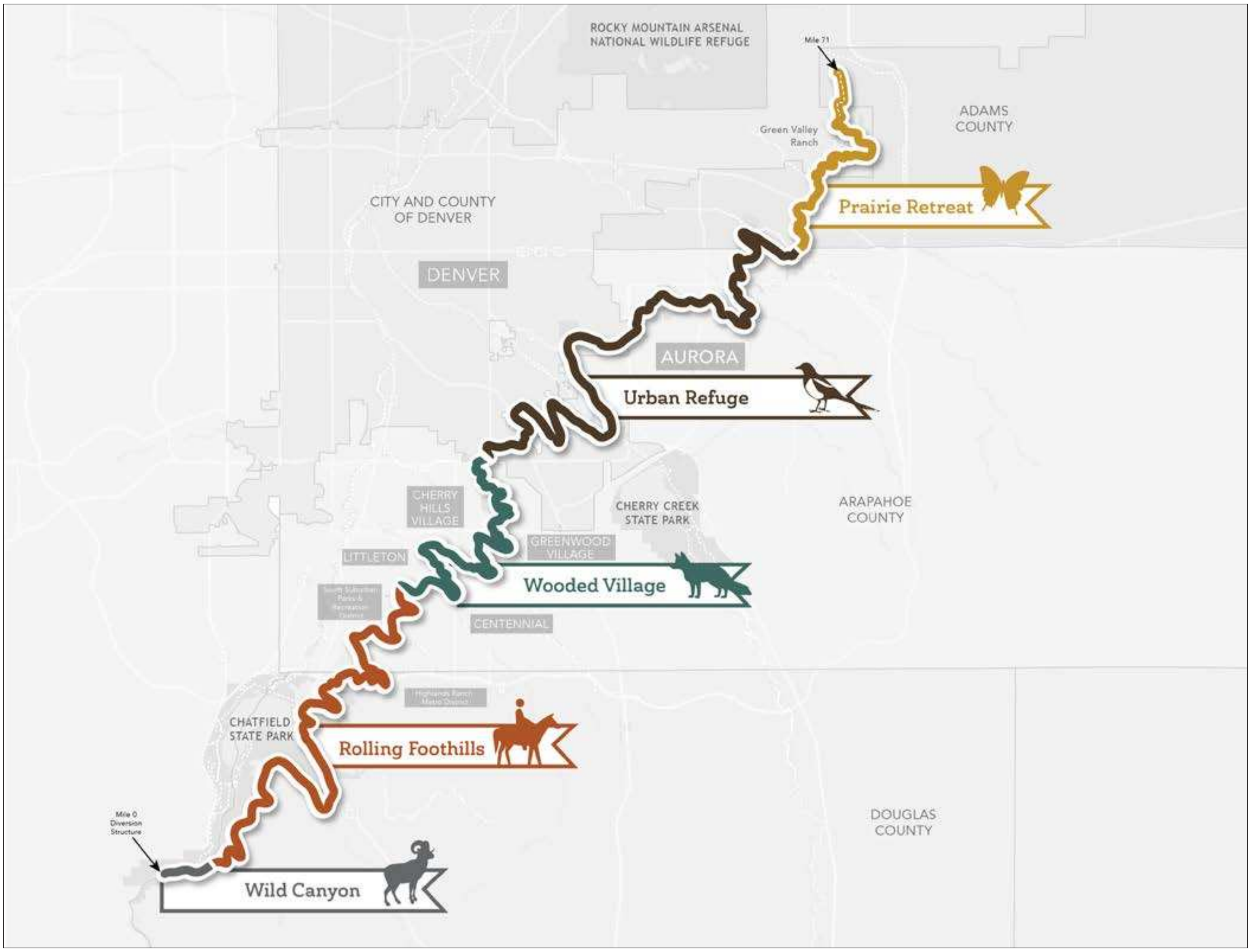


Figure 2.30. The High Line Canal Trail supports diverse bee communities within the Denver metro area and is one example of a habitat corridor that connects different habitats and can reduce fragmentation in Colorado's urban landscapes. (Image: High Line Canal Conservancy.)

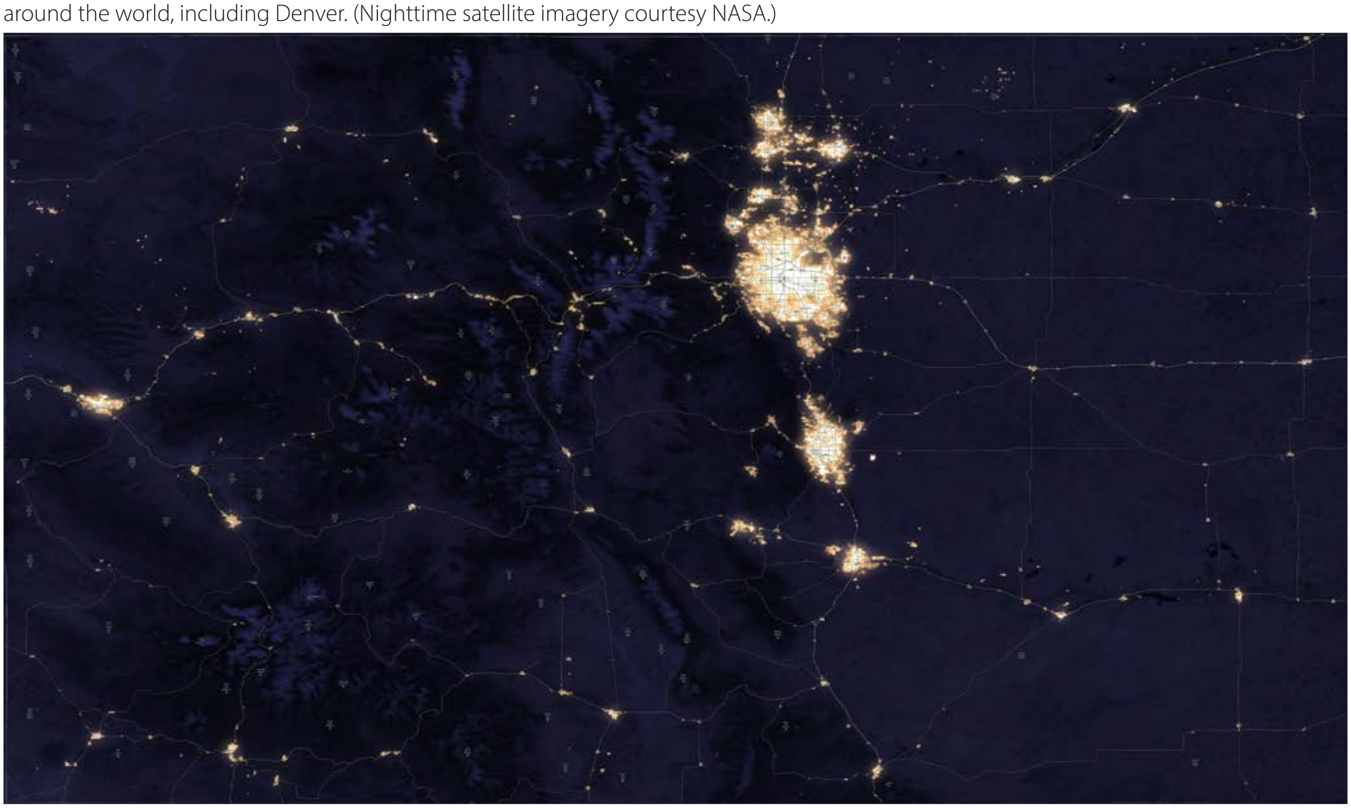
showed that bee abundance and diversity declined with increasing urbanization both pre- and post-flood. Sites most impacted by flooding across the urban corridor had fewer native bees immediately post-flood (Mullins 2021), likely a result of direct mortality associated with the flood itself as many ground-nesting bees were likely inundated or buried, and above-ground nesting bees simply washed away. However, bee communities were also impacted indirectly through changes in flower and nesting resources across the urban corridor, at least in the short term.

Like conversion to agricultural land use, **urbanization can also lead to increased use of and pollinator exposure to pesticides on residential and municipal land**. Increasing acreage of managed turfgrass in residential spaces—which in itself represents a loss of habitat for native pollinators—is often accompanied by increased pesticide inputs (Robbins and Birkenholz 2003), posing an additional threat to native pollinators in these areas. A US Geogolical Survey study of two tributary streams of the South Platte River in Colorado draining from agricultural and urban areas found 30 pesticides in the agricultural streams and 22 pesticides in urban streams (Kimbrough and Litke 1994). The majority of samples collected from shallow Denver groundwater contained detectable pesticides (Bruce and McMahon 1996). Loss of habitat and intensive residential pesticide use may interact to increase negative outcomes for pollinators in urban environments.

A newly recognized impact of urbanization is artificial light at night, which could have direct and indirect effects on urban insects. Artificial light at night (ALAN), comes from streetlights, buildings, homes, and other lit areas. This light can directly impact insects through direct mortality, but also indirectly impact them through changes in behavior or species interactions. For example, cheatgrass, a ubiquitous invasive grass (see Section 2.3.8 Non-native Plants and Pollinators), grows in a higher proportion of sites with light poles around Denver (Murphy et al. 2021) and grows 5 times higher under ALAN than other plant species (Murphy et al. 2022), suggesting that urban light pollution could be an important factor facilitating its invasion across urban habitats and impacting native flower communities. Moreover, ALAN around Denver has also been shown to impact caterpillar growth, resulting in a 49% reduction in body mass of larvae of the rustic shoulder-knot (*Apamea sordens*) moth, driven by both direct effects on moth larval growth, but also indirectly through changes in their host plants (Grenis and Murphy 2019). This suggests that ALAN could have important fitness consequences for moths and butterflies in urban landscapes.

Urbanization is a major source of habitat loss for pollinating insects in Colorado. The permanent conversion of natural or semi-natural lands into urban and suburban landscapes results in reduced and altered foraging and nesting resources for pollinators. Research in the Front Range has shown that bees are responding to urbanization in guild- and species-specific ways, which underscores the need for studies that measure community-level responses. In addition to habitat loss, other urban environmental concerns such as elevated temperatures and artificial light at night are likely to impact pollinators in ways that are not yet well understood. However, research in Colorado also suggests that increasing floral diversity (particularly of native plants) and habitat connectivity can help to mitigate the effects of urbanization and support pollinator communities in urban and suburban areas.

Figure 2.31. A growing body of evidence is pointing to artificial light at night as both a direct and indirect driver of insect decline in cities around the world, including Denver. (Nighttime satellite imagery courtesy NASA.)



2.3.5. Grazing & Rangeland Management

Takeaways:

- Pollinators are abundant and diverse in rangelands, which cover two thirds of Colorado.
- Very little research has addressed the effect that livestock grazing has on pollinators in Colorado.
- While high-intensity grazing, globally, is linked with pollinator declines, properly managed grazing can balance production with the needs of pollinators, and, when used as a restoration tool, could actually promote pollinator communities.
- More research is needed on the efficacy of targeted grazing practices (which incorporate not just intensity, but timing, duration, and frequency of grazing) in supporting pollinators.
- Precipitation, grazing history, and current grazing management practices are likely to influence the effect that grazing has on pollinators across the diverse rangelands of Colorado.
- Livestock grazing practices can change floral resources as well as nesting sites and resources and these factors can shift pollinator communities.
- Future research efforts should address the impacts of different grazing management practices across Colorado's rangeland types on a variety of pollinators.

Rangelands, often natural or semi-natural, cover 65% of our state, and therefore, represent both a huge area affected by human activities and also an impactful opportunity for targeted pollinator-conservation efforts. Colorado's rangelands are used to support the grazing of domestic livestock, in addition to wildlife. Though wild grazers and browsers can influence the floral resources available to pollinators, we focus here on the impacts of domestic livestock. Livestock production is a significant component of Colorado's agricultural economy (over $5 billion in 2020 [USDA/NASS 2022b]), with much of the state's livestock dependent on healthy and expansive rangelands for grazing. Native pollinators are abundant and often incredibly diverse in arid and semi-arid rangelands and are important for the health of these ecosystems. Globally, high-intensity livestock grazing is associated with reduced abundances of both bees and butterflies (Roulston and Goodell 2011; Bussan 2022). Livestock grazing and rangeland management may influence pollinator communities through changes in native plant communities (due to consumption by livestock, plantings by land managers, and invasion of non-native plant species) and changes in soil and nesting resources. Little research has been done in Colorado on the effects of grazing on native pollinating insects, but effects likely depend on the type of rangeland, the intensity, timing, duration, and frequency of grazing, and the effects of management on flower and nesting resources.

Globally, grazing intensity has been identified as a key factor determining pollinator abundance; while high-intensity grazing can decrease pollinator numbers, low-intensity grazing can benefit pollinators. A review of the impacts of land management on bees in 2011 concluded that, in general, higher-intensity grazing (which is determined relative to the productivity of each ecosystem) has negative impacts on bee populations, but that grazing can have positive impacts on bee populations if it has a positive impact on floral resources (Roulston and Goodell 2011). Similarly, a global meta-analysis on restoration efforts found that grazing, when managed with the goal of restoration of plant communities, also benefited bee populations (Tonietto and Larkin 2018). Butterflies seem to respond similarly to grazing intensity as bees. A global review of the influence of cattle grazing on butterflies in grasslands found that low- to moderate-intensity grazing was more likely to have a positive effect on butterflies, while high-intensity grazing was more likely to have a negative effect (Bussan 2022). Research from the tallgrass prairie of Minnesota, however, warns that bees and butterflies can respond very differently to grazing (Leone et al. 2022), so both groups must be measured when considering grazing management in Colorado.

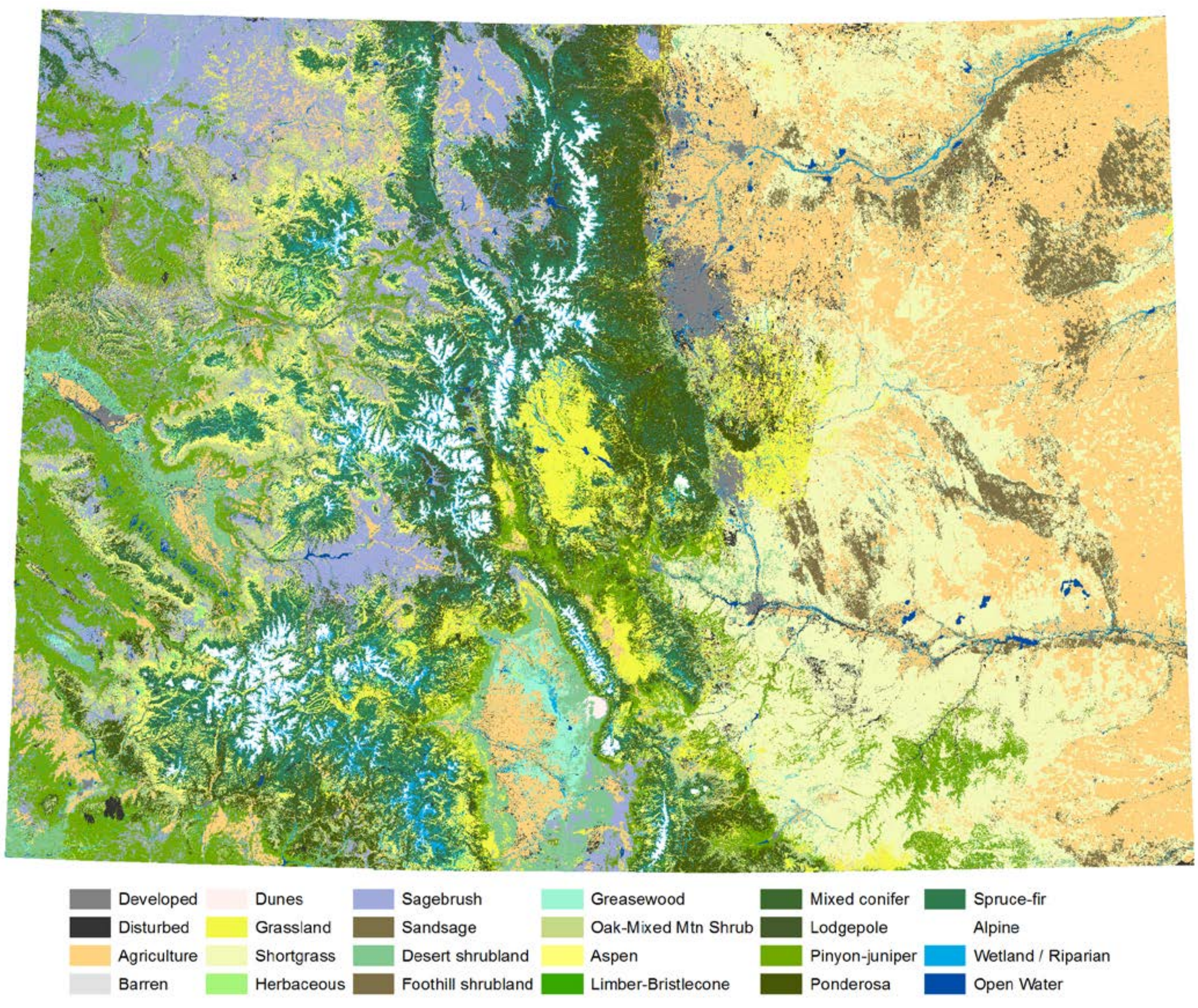
Figure 2.32. Domesticated livestock, like the cattle shown above, are a common part of landscapes across Colorado and can dramatically impact soil and vegetation. More research is needed to determine the best grazing management practices for protecting pollinators in Colorado's rangelands. (Photo: K. Wommack.)

Though most of the limited research on grazing that has included pollinators has focused on grazing intensity, ranchers and land managers often develop grazing practices that regulate the intensity, timing, duration, and frequency of grazing based on the rangelands that they manage. These other factors can alter the effects of grazing intensity. For example, high-intensity short-duration grazing is promoted in many rangeland systems. **Targeted grazing is an emerging area of research that, intuitively, could allow rangelands to support pollinators better, though little research has investigated this.** Recently, researchers in a semi-arid rangeland in Washington state found that delaying grazing until after peak bloom mitigated the impacts of grazing on bees (Mitchell et al. 2023). Rest–rotation grazing, in which livestock are rotated through several pastures to allow ecosystems time to rebound between grazing periods, was shown, in sagebrush rangelands in Montana, to result in greater density of moth and butterfly caterpillars on the ground in rest–rotation pastures than pastures that had not been grazed in at least a decade (Goosey et al. 2019). This study measured density of other invertebrates as well, but used pitfall traps, which only catch insects traveling on the ground, therefore excluding flying insects and insects who are found only on plants, which represent most pollinators. Future research on the efficacy of targeted grazing practices in promoting pollinator communities in Colorado's rangelands would be extremely useful in informing management decisions.

Global synthesis also suggests that precipitation and the long-term history of grazing may be important for predicting how pollinator populations respond to livestock grazing in different ecosystems. Grazing in wet grasslands was more likely to have a positive effect on butterflies than grazing in dry grasslands (Bussan 2022). In contrast, a recent meta-analysis of global studies on the impacts of grazing on bees and butterflies across a wide variety of rangelands found that high-intensity livestock grazing had a negative impact on pollinator diversity in wet but not dry environments. They also found that, in semi-arid rangelands, it mattered whether there was a long history of grazing in the ecosystem, suggesting that the plants were adapted to grazing. In semi-arid rangelands where grazers were present for thousands of years, livestock grazing did not influence pollinator abundance or diversity. In semi-arid rangelands where there was only a recent history of grazing, however, livestock grazing negatively affected pollinators (Thapa-Magar et al. 2022). As more research has been done in Europe, these global syntheses reflect more results from Europe than North America. Until more work is done in the western United States, it is unclear how applicable these global trends are to Colorado. However, these global findings are important for suggesting future research priorities, particularly for indicating what landscape factors might recommend different grazing practices in different landscapes in the state.

Colorado has nine distinct rangeland types, from semi-desert, to east slope foothills, to alpine, which vary in precipitation and long-term history of grazing, factors that are likely to influence how grazing impacts pollinators. Most work on how grazing influences ecosystems in Colorado has been done in the shortgrass prairie of the Eastern Plains. One study in the Front Range, for example, where bison historically grazed, found that flower abundance and diversity weren't impacted by cattle grazing (Thapa-Magar et al.

Figure 2.33. Colorado is home to a great diversity of habitats, as shown above categorized by the dominant vegetation type (or what plant species dominate the landscape). Grazing is a dominant land-use in nearly three-quarters of these 16 categorized vegetation types. The best approach to grazing practices that promote healthy pollinator communities is likely to differ across these habitats. (Source: Colorado Natural Heritage Program, based on LANDFIRE data.)



2020). However, the history of grazing may be quite different in Colorado's mountains, which make up approximately 40% of the state's rangelands. The Western Slope of Colorado is also likely to have a different long-term grazing history than the Eastern Plains, with historical grazing primarily by migratory deer, elk, and bighorn sheep. Global trends support the need for research to address how grazing impacts pollinators in these different regions. Subalpine rangelands are also particularly vulnerable to climate change, and it is unknown how climate change and grazing interact to impact pollinators at high elevations in Colorado. Additionally, because wetlands and rivers provide water and food for livestock during dry seasons, the pollinator communities found in those areas may be more vulnerable to grazing (Swanson et al. 2015). In Colorado, riverside habitats can be important for butterflies whose host plants can only grow in wet soils (Simonson et al. 2001). For example, two threatened butterfly species rely on plants that grow in riverside habitats in Colorado's rangelands, the Nokomis fritillary (*Argynnis nokomis nokomis*), formerly known as the Great Basin silverspot, and the large marble (*Euchloe ausonides*). Though much of Colorado's rangelands are semi-arid, wetter habitats, such as montane and alpine wet meadows, are not uncommon. Global research suggests that precipitation levels should be addressed when considering the impacts of grazing in Colorado. More research is needed to understand how rangeland management strategies can best support pollinator conservation across the state's diverse rangeland habitats.

Though floral resources are often a key factor supporting or limiting pollinator communities, other factors can make pollinators vulnerable to the negative effects of grazing. For example, recent research suggests that the effect of grazing on nesting resources is more important to pollinators than grazing effects on flower resources (Thapa-Magar et al. 2022). Two global meta-analyses investigating the impacts of grazing on insects showed that insects seem to be more sensitive to grazing than plants (van Klink et al. 2015; Wang and Tang 2019). The study in the Front Range described earlier, found that, even though flower abundance and diversity weren't impacted by cattle grazing, bee abundance and diversity were lower in cattle-grazed habitats (Thapa-Magar et al. 2020). Research in Oregon has suggested that bumble bees may respond more strongly to changes in flower availability while other types of bees are more influenced by nesting resources (Kimoto et al. 2012). Work from the tallgrass prairie in Iowa has shown similar patterns for butterfly communities, where grazing increases the abundance of some species and reduces others (Vogel et al. 2007). A review on pollinator health in the Great Plains suggests testing how individual pollinator species respond to grazing (Buckles and Harmon-Threatt 2019). This research stresses the need for rangeland management studies in Colorado that specifically measure the impacts of grazing on different pollinators.

Livestock alter nesting sites and nesting resource availability for pollinators in rangelands. In general, livestock change the soil in rangelands, creating denser, less-structured soils, and also hotter and drier soils (Buckles and Harmon-Threatt 2019) which could impact Colorado's predominantly ground-nesting insect pollinators. Compacted soils may be beneficial for some pollinators and detrimental for others (Kimoto et al. 2012). Livestock grazing in Colorado can also result in more bare ground and less plant-based nesting materials (Moulton et al. 1981; Welch et al. 1991). These changes can favor pollinators with certain life-history traits over others and shift the composition of pollinator communities. For example, along the Front Range of Colorado, early season bee communities are altered by cattle grazing (Thapa-Magar et al. 2020). Grazing increases the relative-abundance of below-ground nesting bees (which favor bare-ground for nesting) and decreases the relative abundance of above-ground nesting bees, which rely upon litter or wood for nesting. More research is needed to address how grazing influences soil and litter in different rangelands and how these changes influence pollinators.

The integrity of rangelands is also threatened by the invasion of non-native species such as cheatgrasses (*Bromus* spp.), which could potentially impact livestock as well as pollinators. Cheatgrass does not provide nectar and pollen resources for pollinators and can displace native wildflowers. However, the presence of cheatgrass in one Front Range rangeland system did not reduce bee populations and may have even benefited early season bees by improving cover and nesting opportunities (Thapa-Magar et al. 2020). Some other weedy species that are commonly found in Colorado, especially clover (*Melilotus* spp., Fabaceae) and thistle (*Cirsium* spp., Asteraceae), provide important floral resources for many bee species in semi-arid rangeland systems (Thapa-Magar et al. 2023). We further discuss the complexities of the impacts of invasive plants on pollinators in section 2.3.8, Non-Native Plants and Pollinators.

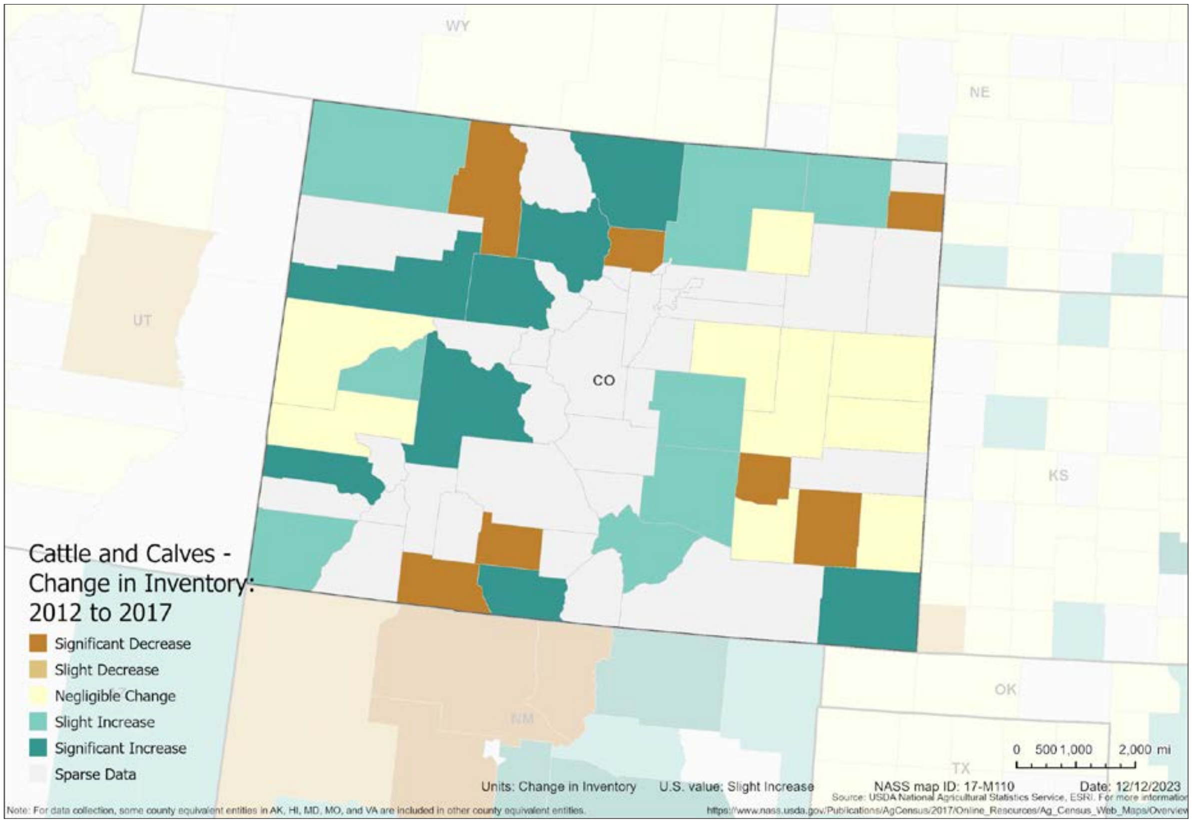
Rangelands are sometimes converted to support management of threatened or endangered species, which may have consequences for native bee communities. One common restoration practice in sagebrush rangeland systems is to reduce densities of pinyon pine and juniper trees. Doing so recruits sagebrush into habitats used by the greater sage-grouse (*Centrocerus urophasianus*, threatened) or the Gunnison sage-grouse (*C. minimus*, endangered), two bird species that are publicly recognizable, threatened, and endemic (found only in Colorado). In a recent study, conversion of pinyon and juniper habitats to sagebrush using mastication techniques (mechanical grinding or shredding to remove woody shrubs) shifted the plant community from one dominated by woody plants and trees to one dominated by herbaceous species. Bee abundance and diversity were unaffected, but bee–flower interactions were 33% more diverse in sagebrush-converted habitats (Thapa-Magar et al. 2023). This study highlights the potential for co-benefits to pollinators of restoration efforts aimed at other species.

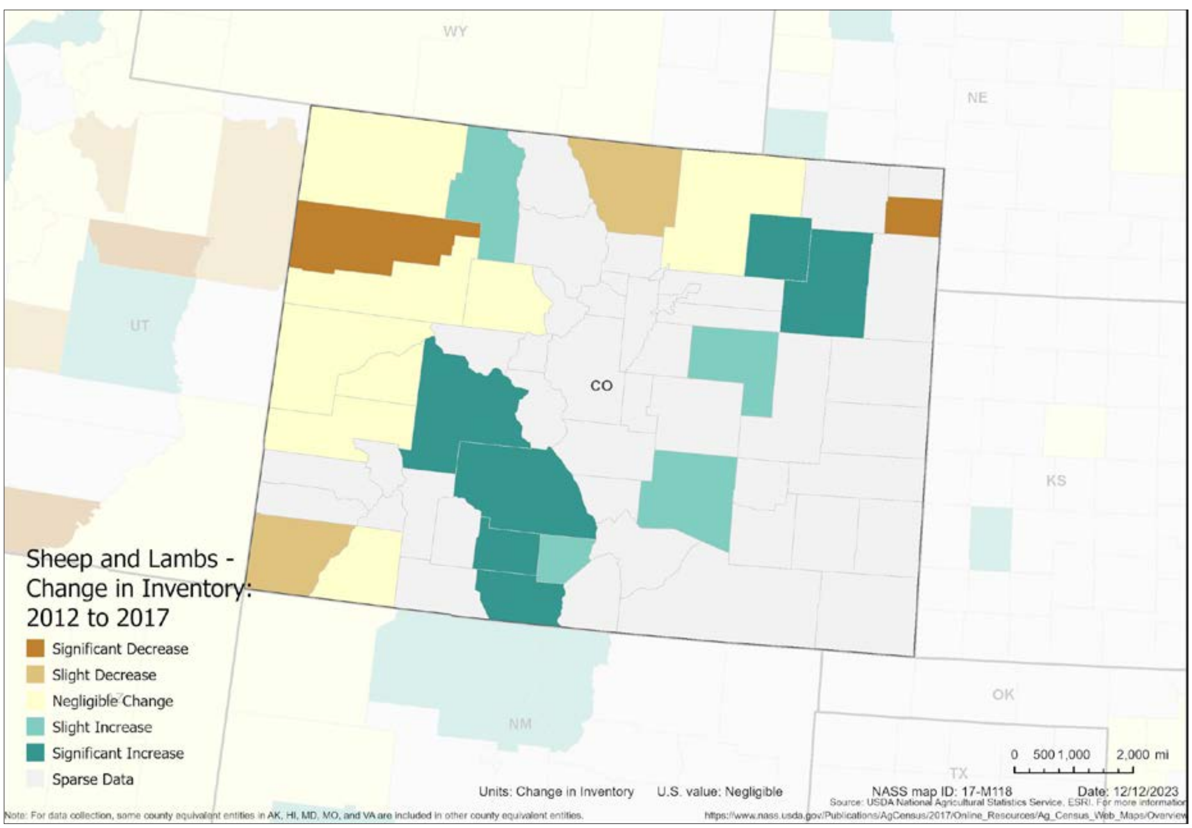
Degraded rangelands, which can no longer support grazing, are sometimes restored through plantings designed to improve forage for livestock and wildlife and to decrease erosion. **There is evidence that commercially available restoration seed mixes could be better optimized to support pollinators, particularly through consideration of the timing of flowering for the species included** (Harmon-Threatt and Hendrix 2015; M'Gonigle et al. 2015; Havens and Vitt 2016). Common restoration mixes used in Colorado, however, have not yet, to our knowledge, been evaluated for pollinator conservation.

There is also a lack of research, worldwide, on how different livestock species impact pollinators (Thapa-Magar et al. 2022). A study in the shortgrass prairie of North Dakota found that cattle grazing resulted in higher abundance and diversity of flowers and higher abundance of butterflies than sheep grazing (Cutter et al. 2022). In Colorado, cattle and sheep are the dominant grazing livestock, but often are grazed in very different areas (Figure 2.34) and very different processes may be relevant for how sheep in the alpine, for example, impact pollinators versus cattle in the shortgrass prairie.

The great diversity of pollinators in Colorado's rangelands, which cover more than half of the state, means that rangelands are crucial to pollinator conservation efforts. At this point, very few studies have addressed the impacts of livestock grazing and rangeland management practices on pollinators in Colorado. **Future efforts that investigate how the intensity, timing, frequency, and duration of grazing by different livestock species, as well as restoration efforts, impact pollinators across the diversity of rangeland types in Colorado would contribute greatly to understanding how rangeland managers might support pollinator communities.**

Figure 2.34. Patterns of livestock rearing vary across Colorado's counties and by livestock species, as shown for cattle and calves (top) and sheep and lambs (bottom). This interacts with variation in habitat type across the state. The resulting complex mosaic of grazing scenarios highlights the need for more research in Colorado on how targeted grazing strategies that are heavily informed by the local landscape might best protect pollinators. (Source: USDA/NASS.)





2.3.6. Forests & Fire

Takeaways:

- Colorado's conifer forests provide native pollinating insects with important floral resources early in the season, as well as woody material for nesting.
- Forests with more open canopies have a greater abundance and diversity of flowering understory plants, which results in greater abundance and diversity of native pollinators.
- Wildfire, beetle outbreaks, and forest restoration can all result in a more open canopy, with positive impacts for pollinators.
- These disturbances can also benefit pollinators through increases in woody material for nesting, but restoration practices that remove wood have the potential for negative impacts on pollinators.
- Current forest-restoration practices may have co-benefits for Colorado's native pollinating insects, but more research is needed on this topic.

Colorado has some of the most diverse and extensive forests within the Intermountain West. Covering nearly a third of the state, these forests have long been managed by Indigenous groups, prior to Euro-American settlement. Since settlement, forests have been managed by natural resource professionals for the production of forest products, to create wildlife habitat, and to prevent wildfire. This long history of human land use, in combination with other environmental changes, has structured the complex distribution of Colorado's forests. Some regions are now more forested than historically, while other regions have lost huge tracts of forest, the latter especially driven by the recent outbreak of catastrophic wildfires (Rodman et al. 2019). **Although there has been a tremendous amount of ecological research, both fundamental and applied, on the forests and woodlands of Colorado, substantially fewer research programs have considered insect pollinators in forest management or conservation.** There has been a great deal of research on pollinators in forests in other regions of the country and around the globe, including the importance of forests to both pollinator conservation and the sustainability of pollination services (Hanula et al. 2016; Mola et al. 2021; Ulyshen et al. 2023). However, Colorado's primarily coniferous forests are distinct from other forests in ways that are likely to be important to pollinators. Luckily, a small but growing contingent of researchers within Colorado are beginning to study how ongoing forest change, forest management, and future forestry practices may impact native pollinating insects.

In Colorado's conifer-dominated forests, the primary floral resource for pollinators lies in the flowering understory plants, rather than the trees. Forest habitats generally don't support as many pollinators as other ecosystems. Globally, bees, for instance, are most diverse in warm, dry landscapes such as grasslands, steppe, and prairies (Michener 1979). Forests are an exception to the general pattern that greater plant productivity and diversity means greater bee diversity (Orr et al. 2021), because bee diversity declines with increasing forest cover in many regions. There is evidence that similar patterns exist within Colorado. In south-central Colorado, for example, pinyon–juniper habitats range from savannah (grassland with dispersed trees) to woodland (mostly forested). One study suggests that the more open the pinyon–juniper habitat, the greater the abundance and diversity of bees (Davis and Comai 2022). The conifers that dominate Colorado's forests do not produce flowers. Instead, pollen is released from male cones and is carried by the wind to female cones. Conifer pollen is low in protein content for pollinators, and the lack of flowers means that conifers also do not provide nectar. Pollinators in Colorado's forest habitats, therefore, must rely on flowering plants that grow in the understory. As a general rule, forests that are more open, with lower tree and canopy density, contain more flowering understory plants, and therefore more floral resources for pollinators.

Although forests potentially provide fewer floral resources overall than more open habitats, **forests can still provide important resources for pollinators: from host plants for caterpillars, to seasonally important floral resources and nesting sites for native bees**. Some caterpillars rely upon forest plants. In Colorado, for example, caterpillars of the two-tailed swallowtail (*Papilio multicaudata*) feed on the leaves of chokecherry (*Prunus* spp., Rosaceae) and ash (*Fraxinus* spp., Oleaceae). Gillette's checkerspot (*Euphydryas gillettii*) feeds primarily on the forest shrub twinberry honeysuckle (*Lonicera involucrata*). Some caterpillars even feed on conifer needles. The pine white butterfly (*Neophasia menapia*) specializes in ponderosa pine (*Pinus ponderosa*, Pinaceae) and the western pine elfin (*Callphrys eryphon*) feeds on limber (*P. flexilis*, Pinaceae), lodgepole (*P. contorta*, Pinaceae), and ponderosa pines. The adults of these species visit flowers in forest gaps for nectar.

Forests can also provide important floral resources for bees that emerge early in the season, when flowers are limited (Ulyshen et al. 2023). In Colorado, early season bees such as mason bees (*Osmia*) and mining bees (Andrenidae) rely upon the flowers of understory shrubs including those in the rose family (e.g., chokecherry [*Prunus virginiana*], wild plum [*P. americana*], and Saskatoon serviceberry [*Amelanchier alnifolia*]), and the heath family (e.g., kinnikinnick [*Arctostaphylos uva-ursi*] and whortleberry [*Vaccinium myrtillus*]), as well as Oregon grape (*Mahonia repens*). In addition to early season flowers, forests provide bees with critical nesting and overwintering sites (Mola et al. 2021). Cavity-nesting bees, for example, can lay their eggs in beetle holes in deadwood. Deadwood can also harbor the larvae of flies and beetles that visit flowers. Ground-nesting bees may also prefer nesting in forests. No studies to date have been conducted within Colorado on how these multiple forest resources (abundance and diversity of caterpillar host plants, early flowering understory plants, and nesting resources) work together to structure pollinator communities. It is clear, however, that all of these important pollinator resources are impacted by forest management, as well as events like wildfire.

There is general evidence that **less dense forest canopy (whether created by wildfires, beetle outbreaks, or other natural processes) is likely to be associated with increases in bee abundance and diversity**, with examples from a range of forest systems in Colorado including arid pinyon–juniper ecosystems (Davis and Comai 2022), ponderosa pine forests (Gelles et al. 2022), mixed conifer forests (Rhoades et al. 2018), and even high-elevation spruce–fir forests (Davis et al. 2020). The precise drivers of this pattern vary across forest types but may be related to (1) increased floral resources in canopy gaps or low-density forests; (2) the introduction of weedy species, which can increase the overall time that flowers are available in forests; and (3) changes to physical conditions with canopy opening, particularly from increased sun exposure and warmer microhabitats within sites. It also appears that small canopy gaps are equivalent to large canopy gaps in terms of their ability to increase plant–pollinator interactions (Davies and Davis 2023). However, canopy gap creation may disproportionately benefit native bees with social behaviors, as solitary species forage for fewer days each season and are more likely to miss the peak availability of high-quality pollen during their narrow foraging windows (Davies and Davis 2023). Wildfire, beetle outbreaks, and fire-mitigation strategies such as prescribed burns and thinning can all create less dense forest canopies. New research in Colorado is beginning to reveal how these various disturbances influence pollinator communities.

Given that wildfire mitigation is one of the biggest factors driving forest management, surprisingly little research has been done on the effects of wildfires on pollinators (Carbone et al. 2019). Globally, fire results in increased pollinator abundance and diversity, particularly in the first few years after a fire (Carbone et al. 2019). After a large disturbance like a fire, many wildflower species increase in abundance in response to the newly available habitat with little competition for light. **In the forests of the Rocky Mountains,**

post-forest-fire increases in wildflower abundance and diversity seem to correspond with increases in bee abundance and diversity. Burned areas in the Rocky Mountains seem to also have more woody material for bee nesting (Burkle et al. 2019). In the foothills west of Boulder, high-intensity fires left more abundant and diverse plant and bee communities 8–10 years post fire, again, likely driven by the increase in open habitat (Gelles et al. 2022). However, globally, fire may decrease butterfly and moth abundance and diversity. Short fire intervals (fires that reburn the same areas within 10–12 years) also seem to have a negative effect on pollinators (Carbone et al. 2019). In the Front Range, a study on the long-term recovery of the pollinator community of wax currant (*Ribes cereum*) over 20 years after different severity fires appears to show no lasting impacts of fire on pollinator abundance or diversity (Bieber 2022). More research is needed to resolve the relationship between fire interval, which has changed throughout Colorado's history (Goldblum and Veblen 1992), and pollinator communities. The severity of fires is also a great concern for forest managers. A recent meta-analysis from University of Denver of published studies on fire effects on arthropods, suggests that increasing severity of fires globally is altering arthropod communities and specifically reducing pollinator diversity (Bieber et al. 2022). There are not enough published studies on how fire impacts pollinators, however, to strongly conclude this. In addition to pollinator abundance and diversity, few studies have considered functional changes of species within pollinator communities following fire (Burkle et al. 2022). In the fire-adapted forests of Colorado, prior to Euro-American settlement, wildfire contributed to heterogeneity (or variation) in forest structure (Allen et al. 2002). In fire-adapted forests today, variation in fire extent, severity, and frequency (pyrodiversity) is likely a dominant driver of both plant and pollinator diversity. The landscape diversity that results from pyrodiversity may even buffer pollinator communities against other environmental stressors like drought (Ponisio et al. 2016). Clearly, more research—specifically in Colorado—could help determine how dependent pollinating insect communities are on fire and the implications for forest management.

Fire risk in Colorado is a leading driver of forest management, and the impacts of fire reduction strategies on pollinators is little studied, though these practices are likely to have large impacts on pollinators. Forest management efforts to reduce wildfire hazard in Colorado are considerable, with several large, federally funded collaboratives such as the Collaborative Forest Landscape Restoration Program (CFLRP) spearheading forest restoration treatments. These initiatives have treated tens of thousands of acres across the Front Range region. Restoration efforts generally focus on prescribed burns and tree thinning (cutting down trees to reduce tree density), which can improve overall forest health and reduce fire severity by reducing fuel and decreasing risks of a crown fire (the most severe forest fire) (Addington et al. 2018). The creation of canopy gaps, through clumped thinning of trees, is also often a goal of restoration projects. Much like wildfire, these restoration efforts increase the light available for the flowering plants that pollinators depend on.

The few research studies done in Colorado suggest that prescribed burns and thinning have positive or neutral effects on Colorado's pollinators. In one study in the Red Feather Lakes region, prescribed fire in ponderosa pine-dominated forests resulted in short-term increases in both flower and native bee abundance and diversity, likely as a result of the positive relationship between flowering herbaceous plants and bees, the former of which is often higher post fire (Gelles et al. 2023). In ponderosa pine forests in the foothills west of Boulder, thinning had no effect on bee abundance and diversity (Gelles et al. 2022). This finding contrasts with those found in other forest types, where thinning seems to have a positive impact on pollinators, and even a study from ponderosa pine forests in Northern Arizona, which found an increase in flowering plants in response to thinning, which may benefit pollinators (Nyoka 2010). The neutral effect in Colorado may be a result of low thinning intensity in this particular study (Gelles et al. 2022). Taken together, there is evidence that CFLRP-based treatments increase the robustness of plant–pollinator networks, diversifying the number of connections between understory flowering plants and native bees (Davies et al. 2023). More research is needed to assess the impacts of prescribed burns and thinning on pollinator communities in the different forest types of Colorado, as well as the effect of thinning intensity.

Figure 2.35. The impact of fire on pollinators depends on intensity, timing, and how variable fire is across a landscape. However, there is potential for fire to benefit pollinators by increasing the abundance of flowering plants, like the fireweed (*Chamaenarion angustifolium*) shown above growing after a fire. (Photo: Blue Canoe, Flickr; BY-NC-ND 2.0)

Though prescribed burns and thinning are likely to be beneficial for pollinators, some associated effects, such as the removal of deadwood from forests, and the use of heavy machinery, may have negative impacts. In addition to thinning, forest managers in Colorado often remove deadwood from forests in order to reduce fuel for fires. However, there are pollinators for which woody materials (the primary target of fuels reduction) are critical for sheltering and nesting, though the value of woody materials for pollinators has been little studied, much less the impacts on its removal. In one study in Boulder County Open Space, the removal of woody materials following flooding in 2013 resulted in a 40% reduction in bee abundance, including both cavity-nesting (bee species that nest in dead and decaying wood or hollow stems) and non-cavity-nesting species—and overall bee abundance was positively related to the amount of woody materials in any given site (Carper and Bowers 2017). Pile burning, in particular, is commonly used in Colorado's lodgepole pine forests after bark beetle outbreaks. Studies in Colorado's spruce–fir forests indicate that the deadwood that results from bark beetle outbreaks can actually benefit native bees (Davis et al. 2020). Although some ecological impacts of post-outbreak pile burning have been studied (Rhoades and Fornwalt 2015), pollinator communities have not yet been considered. Nearly a third of Colorado's native bees are cavity-nesting or cavity-dependent species (Scott et al. 2011), suggesting that wood management practices could have large effects on bee communities, depending on the nesting strategies of different species. In addition, restoration efforts often utilize heavy machinery, which may condense forest soils and have negative impacts on ground-nesting bees and caterpillars. Forestry practices designed to minimize the impacts of machinery on soil (Nyoka 2010; Page-Dumroese et al. 2010) may also represent the best solution for conservation of soil-nesting insects, but this has yet to be studied. The response of pollinator communities to these aspects of forest management likely represents a much-needed avenue for future research.

Aspen trees are Colorado's only widespread, native, deciduous tree and the forbs and shrubs in aspen understory can be important floral resources for native pollinators. Surveys of aspen understory diversity have reported more than 48 species of forbs and shrubs (Trudgeon 2023) and most of these are species visited by bees. Aspen forest, which covers 20% of the state's forested land, has a broad altitudinal range and is primarily distributed on the West Slope (csfs.colostate.edu/colorado-forests/forest-types/aspen/). Aspen forests face a variety of threats and are declining in many areas. For example, Coop et al. (2014) found that there were pronounced declines in plots sampled from 1994 to 2010, compared to their original densities in 1964. Drought and increasing temperatures are likely major contributors to the decline (Huang and Anderegg 2012; Anderegg et al. 2013). Despite the overstory losses, Coop et al. (2014)

Figure 2.36. Colorado's pollinators benefit from more open forest canopies, which are naturally created by disturbances like fire and beetle outbreaks. Fire-mitigation strategies like thinning, pictured above, have the potential to similarly benefit pollinators by increasing the amount of flowering plants in the understory. The increased availability of deadwood can provide nesting sites for pollinators, though the wood piles shown above are often burned, which may negatively impact pollinators. (Photo: Big Thompson Watershed Coalition.)

found relatively little change in understory plant communities dominated by large perennial herbs. Although aspen forests are not likely to suffer major mortality from fires, historically there have been stand-replacing disturbances. In some areas, roller felling is now used to encourage regeneration, reset successional stages, and reduce fire fuel loading (Trudgeon 2023). The long-term impacts of aspen forest change and management on pollinating insects is still unknown, but warrants further research.

Overall, the dearth of studies on pollinators in coniferous forests hasn't gone unnoticed and some conservationists and forest managers alike are beginning to develop goals and strategies for their incorporation into forestry practices. However, the hurdles to addressing pollinators in western forests, in particular, are many. Results from a workshop on pollinator management within coniferous forests hosted in Corvallis, Oregon, found that a lack of ecological information about pollinators in forests, management-related impacts on pollinators, and training in pollinator management (and related research methods) were the biggest impediments to incorporating pollinators into forest management and decision making (Rivers et al. 2018). This focus group suggested that future research focus on 1) the need for baseline inventories of pollinator diversity within forests; 2) assessment of the direct & indirect effects of different forest management activities on pollinators; and 3) quantifying the effects of natural disturbances, such as fire, on pollinator communities (Rivers et al. 2018). In Colorado, limited evidence does suggest that forest restoration methods that are currently being employed to reduce the risk of catastrophic wildfire may have co-benefits in promoting native pollinators, but more research is needed across Colorado's diverse forest types.

2.3.7. Pesticides

Takeaways:

- Many of the pesticides that are commonly used in Colorado can be harmful to native pollinators.
- Both insecticides and other pesticides (including herbicides and fungicides) can have lethal and sublethal effects on pollinators, particularly when multiple pesticides are mixed together.
- There is evidence that pesticides are contributing to loss of pollinators worldwide, including some threatened species found in Colorado.
- Very little research has been done on the impacts of pesticides on pollinators in Colorado, but pesticides are ubiquitous in urban and agricultural lands.

Many of the pesticides that are commonly used in Colorado have negative effects on the health of pollinators. A great deal of research has been done on the toxicity and other negative health effects of pesticides to pollinators. Though most of this research has been done outside of the state, it is relevant for pollinator species in Colorado. Efforts are now being made to establish how much pesticides are contributing to pollinator declines, and available evidence suggests that pesticides represent a significant threat to pollinators. Most of the information on how pesticides affect pollinators comes from research on honey bees, and very little research on native bees has been conducted. Here, we briefly discuss the global research findings on the impacts of pesticides on pollinators, focusing on two types of pesticides that are particularly relevant in Colorado.

Pesticides include a variety of chemicals that are used to kill or harm living things, including insecticides (targeting insects), herbicides (targeting plants), fungicides (targeting fungi), and biopesticides (derived from natural sources like microbes). Not surprisingly, the earliest research to address the effects of pesticides on pollinating insects focused on insecticides, as they are the most toxic to insects. **There is evidence that insecticides used in farmlands, parks, and yards are harmful for native pollinating insects around the world** (Godfray et al. 2015). Neonicotinoids are a class of insecticides that have received widespread attention due to characteristics that pose particular risks to bees: the four main neonicotinoids (imidacloprid, thiamethoxam, clothianidin, and dinotefuran) are systemic, persistent in the environment, and have high toxicity to honey bees and other bee species at low doses (Hopwood et al. 2016). Because they are systemic, neonicotinoids can move into pollen and nectar, potentially posing risks to crop pollinators like bumble bees and blue orchard bees (a managed agricultural pollinator in Colorado) (Scott-Dupree et al. 2009). Though most research has focused on bees, neonicotinoids can also harm other pollinating insects. These pesticides are commonly applied to agricultural seeds, which allows them to be released into the soil, where they can be taken up by other plants. Neonicotinoids are also applied to ornamental nursery plants at very high levels. Caterpillars that consume these pesticides when eating their host plants experience reduced survival, as has been shown for caterpillars of the monarch (*Danaus plexippus*) and painted lady (*Vanessa cardui*) butterflies (Krischik et al. 2015; Knight et al. 2021). Other insecticides, whether encountered individually or in combination with other pesticides, can cause lethal and sublethal effects on bees (Tosi et al. 2022). Pyrethroids, organophosphates, and avermectins are among the other insecticide classes with chemicals in common use that have high toxicity to honey bees and other pollinating insects.

More recently, researchers have recorded negative health effects in pollinators resulting from a wide range of pesticides beyond insecticides. Though they are generally less toxic to insects, fungicides and herbicides can have a range of sublethal harmful effects on the growth, reproduction, learning, disease resistance, and behavior of pollinating insects (Iwasaki and Hogendoorn 2021; Cappa et al. 2022; Tosi et al. 2022). The Xerces Society has cataloged evidence of the effects of pesticides on insects (www.pesticideimpacts.org/). Even chemicals that aren't dangerous on their own can become harmful to pollinators when combined with other chemicals, or can increase the toxicity of insecticides (Iwasaki and Hogendoorn 2021; Cappa et al. 2022; Tosi et al. 2022). Exposure to multiple pesticides is common in many settings. Pesticides can also interact with other stressors such as climate change and habitat loss to further threaten bees (Goulson et al. 2015). Sublethal effects can also result from chronic exposure of pollinators to insecticides at doses that are too low to kill (Desneux et al. 2007; Olaya-Arenas et al. 2020). While much more work is needed to address the role of sublethal pesticide effects on the diversity of pollinating species, these effects seem common and have not generally been addressed in policies and decision-making regarding pesticide use.

The majority of research on the effects of pesticides on pollinators has been done on honey bees. Comparative studies with wild bees have indicated variable sensitivities to pesticides relative to honey bees (Arena and

Sgolastra 2014; Spurgeon et al. 2016). Though neonicotinoids are likely to have similar physiological effects on most bees, an increased understanding of species-level responses in the wild bees of Colorado could help inform where the greatest need for control of exposure lies. Additionally, while the honey bee may sometimes be more sensitive in individual-based pesticide toxicity assessments, trait-based analyses suggest that wild bees may be generally more vulnerable and less like to recover from pesticide exposures than honey bees, which are buffered by large social colonies (Schmolke et al. 2021). Additionally, pollinating insects whose larvae feed on pesticide-treated plants are likely to be even more strongly impacted.

Pesticides can also have indirect effects on pollinating insects through environmental changes. Herbicides in particular can change the floral resources available for pollinators. For example, herbicide use in agricultural fields can decrease floral resources for pollinators (Bohnenblust et al. 2016) and declines in monarch populations may be partially attributable to the effects of herbicides on their host plants, milkweeds (Pleasants and Oberhauser 2013). Herbicides, however, are also used in restoration efforts to suppress invasive plants and promote natives, which can benefit pollinators. For example, control of cheatgrass (*Bromus tectorum*) with the herbicide indaziflam (typically targets grass through inhibition of cellular biosynthesis) in heavily invaded rangelands in Boulder County resulted in increased flowering plant diversity within two years (Arathi and Hardin 2021), although no corresponding measures of pollinators were taken. Another study found similar results when indaziflam was used to control the cheatgrass *Bromus inermis* on rangelands in Jefferson County. However, these studies were not able to consider long-term effects on plant communities.

Figure 2.37. Caterpillars, like this one of a police car moth (*Gnophaela vermiculata*), consume large amounts of plant material and may be especially vulnerable to pesticides found on their host plants. (Photo: Adrian Carper.)

In contrast, a study in sagebrush steppe in Wyoming found that **indaziflam reduced the cover of native herbaceous plants by 50% and strongly reduced germination of flowering annual and perennial herbaceous plants** (Meyer-Morey et al. 2021). This difference may be because the Wyoming sites were less invaded and relatively intact. So indaziflam may only increase floral resources in heavily degraded sites. Crucially, no studies have investigated the direct impacts of this herbicide on pollinating insects, though indaziflam experimentally increases mortality in clams (Tissot et al. 2022). This is an example of how pesticides can have nontarget effects and why it is critical to monitor pollinators in response to pesticide use, particularly when restoration is the goal.

Pesticides are ubiquitous in Colorado, especially in agricultural and urban contexts. In one study of native bees collected in northeastern Colorado grasslands and wheat fields, researchers found residues of 19 different pesticides within wild bees, including a range of insecticides, fungicides, and herbicides, the most common being neonicotinoids (thiamethoxam, clothianidin, and imidacloprid, in 46%, 24%, and 13% of samples respectively). All of these pesticides were found more frequently in bees collected from wheat fields than grassland sites. However, all compounds were detected in bees from grasslands, suggesting that exposure is not limited to the targeted agricultural fields (Hladik et al. 2016). The USDA Animal and Plant Health Inspection Service (APHIS) releases a yearly report of pesticide levels found in honey bee hives. In 2022, only 19 samples were analyzed for pesticide residues in all of Colorado: 12 samples of comb and bee bread (the mixture of pollen and nectar used as food within the hive) were submitted from Boulder County, four from Weld County, and two additional samples from unknown locations. This represents a tiny fraction of the hives in Colorado and likely are a huge underestimate of honey bee exposure especially across the under sampled agricultural regions. Still, detectable levels of several pesticides were found, including the fungicides carbendazim at 0.0645 ppm, chlorothalonil at 0.050 ppm, and triflumizole at 0.050 ppm (Bee Informed Partnership 2022). At these levels, carbendazim and chlorothalonil could result in sublethal effects (Shi et al. 2018; Neal et al. 2019) and triflumizole could amplify the effects of some neonicotinoids, dropping the LD50 (the dose at which 50% of bees die) down to 0.0290 ug/bee for acetamiprid and 0.0097 ug/bee for imidacloprid (Iwasa et al. 2004). Urban areas of Colorado are also likely to expose pollinators to high levels of pesticides. A study comparing pesticide levels in streams in urban and agricultural areas found that while herbicide levels were much lower in Cherry Creek in Denver than in Lone Tree Creek in Greeley, insecticide levels were significantly higher in the urban creek (Hoffman et al. 2000). Measuring differences in pesticides found across Colorado's lands could be valuable in assessing the potential risks to pollinator communities found.

There is evidence that pesticide use is contributing to population-level pollinating insect declines. While there is ample evidence that pesticides harm pollinating insects, connecting these effects with larger trends in pollinating insect abundance is difficult (Sponsler et al. 2019), particularly for pesticides that cause sublethal health effects. Several studies from around the world, however, have found that declines in bees and butterflies more strongly correlate with pesticide use than other factors, which suggests than pesticides are an important cause of pollinator loss (Gilburn et al. 2015; Forister et al. 2016; Woodcock et al. 2016). In Colorado, pesticides could be especially harmful to rare or at-risk species. Including data from Colorado, a national synthesis of the primary drivers of declining bumble bee species found that greater usage of total fungicides was the strongest predictor of range contractions in declining species, This included three species declining in Colorado, western bumble bee (*Bombus occidentalis*), American bumble bee (*B. pensylvanicus*), and yellow-banded bumble bee (*B. terricola*) (McArt et al. 2017). The decline of the western bumble bee has also been linked to a strong negative relationship with neonicotinoid insecticide use, with 35% lower predicted occupancy of *B. occidentalis* at sites where applications of nitroguanidine neonicotinoids were made (Janousek et al. 2023). Pesticide use has also been implicated as an important threat to imperiled butterfly species in Colorado. To our knowledge, however, no studies in Colorado have investigated the impact of pesticide use on pollinator communities or populations.

The state of understanding of the impacts of pesticides has led to calls from researchers and managers alike to address the impacts of pesticide use on pollinators into the pest management decision making process. Integrated pest and pollinator management (IPPM) (Lundin et al. 2021) presents a framework for co-managing pests and pollinators, taking a more ecosystem-level approach to management decisions. These approaches, along with more research on how the pesticides commonly used in Colorado actually impact the state's diverse pollinator species, would help to resolve the best approaches to mitigating the impacts of pesticides on pollinating insects in Colorado.

Figure 2.38. Pesticide use is common in urban and suburban environments and likely to negatively impact pollinators. (Photo: Lynn Betts, USDA NRCS.)

2.3.8. Non-Native Plants & Pollinators

Takeaways:

- Non-native species have a wide range of impacts, depending on how they change ecosystems.
- Invasive plants can alter plant communities, but little research has documented their impacts on native pollinators.
- Colorado has 12 species of non-native pollinators, most of which are unmanaged with unknown impacts on native pollinators.
- Non-native managed honey bees likely have negative effects on native pollinators and represent a huge need for new training, policy, and community engagement.

Humans have fundamentally changed how plants and animals disperse, and the impacts of non-native plants and animals are a fundamental driver of global biodiversity loss, with wide-ranging ecological, economic, and social impacts (Roy et al. 2023). These impacts vary depending on the degree to which non-native species impact native species and ecosystems, with concurrent foci for management targeting invasive species that have disproportionate effects or pose the greatest risk to native ecosystems or human health and well-being. However, for most non-native species, comparatively little research has been conducted to quantify their impacts and many species are unknown to land managers. In addition, some species that likely have disproportionate impacts on native communities, are still managed for human use as the agricultural or cultural benefits of their cultivation are assumed to outweigh the negative impacts they have on native communities.

Most land managers and conservationists alike are familiar with invasive plants and the impacts that they can have on native ecosystems, and research has been done in Colorado quantifying those effects. However, the majority of invasive-plant research that has addressed pollinating insects has focused on how invasive plants change floral communities, including the temporal and spatial distribution of floral resources that are important to native pollinators, without measuring the actual impacts to native pollinators. For example, around Crested Butte, **yellow toadflax (*Linaria vulgaris*), considered a Class B noxious weed, invades subalpine meadows. In invaded meadows, it comprises up to 97% of all flowers and delays the mean flowering date of the entire flowering community by 23 days** (Wilke and Irwin 2010), potentially altering the availability of floral resources for early pollinators. Globally, there is some evidence that invaded plant communities generally support less-diverse pollinator communities (Bezemer et al. 2014). However, the pollen and nectar of invasive flowers is often well utilized by native pollinating insects, particularly by generalist pollinators (Bezemer et al. 2014). In Rocky Mountain National Park, habitats with greater invasive plant diversity also showed greater adult butterfly diversity, and this relationship was stronger than the relationship with native plant diversity (Simonson et al. 2001). As discussed earlier, there is evidence from Colorado that cheatgrass-invaded rangelands may provide improved nesting resources for bees due to more bare ground (Thapa-Magar et al. 2020) and that weedy species are important floral resources for bees in rangelands (Thapa-Magar 2023). In contrast, tamarisk-invaded sites along the Arkansas River in Colorado support less-healthy butterfly communities (as measured by the riparian butterfly index) than non-invaded sites (Nelson and Wydoski 2008). Given that results of invasive plants on pollinating insects vary from negative to positive, making generalizations isn't possible and results likely depend on the invasive plant species involved and how it modifies the ecosystem.

Nonetheless, due to the negative effects that invasive plants can have on Colorado's native-plant communities and ecosystems, invasive plant control and removal is a high priority for land management in the state. **The impact of these control measures on Colorado's pollinating insects, however, has rarely been studied.** For example, as a Class B species, many management control strategies have been developed to help reduce the abundance of yellow toadflax (see Beck 2014); however, little research has studied the impacts of different strategies on pollinating insects. In one study near Crested Butte, the removal of yellow toadflax led to lower soil N and C mineralization rates, with potential impacts on soil health and function (Rewcastle et al. 2022), potentially impacting native plant recovery, but also removing the most dominant floral resource for pollinators. The use of the herbicide indaziflam to eradicate cheatgrass from highly invaded sites in the Front Range resulted in an increase in native flowering-plant diversity (Arathi and Harden 2021), which should logically benefit pollinators. However, pollinator communities were not measured and no studies have addressed whether indaziflam directly decreases pollinator health, as some other herbicides do. In another study, removal of tamarisk along the Arkansas River in Colorado did not benefit butterfly communities, despite the negative impact of tamarisk invasion on these communities, which the researchers attribute to a lack of subsequent revegetation efforts aimed at actively restoring native plants (Nelson and Wydoski 2008). These limited studies suggest that future research pairing plant and pollinator community response to invasive plant control is crucial for informing best management practices.

In general, **the type of management strategy for an invasive plant should depend on measurable impacts as well as the economic constraints of control** and some research in Colorado has explored both. For example, when considering the economic impacts of yellow toadflax and modeling cooperative management strategies at varying densities of the invasive species, researchers from RMBL suggested that different management strategies were required. They found that removing plants in early invasions, and through cooperative management, could outweigh the cost of management once an invasion established higher densities—the cost to remove the invasive species becomes prohibitively expensive at higher densities (McDermott et al. 2013)—though again, few impacts on pollinators were addressed. Clearly, more studies measuring and modeling both the economic and ecological impacts of invasive plant management are needed.

Less well-known than non-native plants are non-native pollinators. **More than 80 species of non-native bees have been introduced to native ecosystems around the world**, and they can i**mpact native pollinators through competition, by driving ecological and evolutionary change within communities, and introducing novel pests, pathogens, and diseases** (Russo et al. 2021). Most of these non-native pollinators are unmanaged, some are considered pests, and some are even cultivated for human purposes. However, most have either already become, or are becoming, dominant species within our pollinating insect communities. For example, the ubiquitous cabbage white butterfly (*Pieris rapae*) comprised nearly 84% of all recorded individuals in a study of butterfly community dynamics across the foothills and plains of the Front Range, significantly impacting diversity metrics for habitats where they were very abundant (Robinson et al. 2012). Although sometimes considered a pest of cruciferous vegetables, they are infrequently managed, and their impacts on other butterfly species is unstudied. The impacts of most non-native butterflies, flies, and beetles found in Colorado upon native pollinators are also poorly understood.

Similarly, little is known about the impacts of most non-native bee species. At last count, the CU Museum of Natural History found that **12 different species of non-native bees have been introduced to Colorado**, most in just the past few decades. Of these, nine species are wood- and stem-nesting bees, likely introduced as a result of the movement of shipping materials (e.g., wood pallets) around the country and globe. At least two species are currently managed for agricultural purposes: the alfalfa leafcutting bee (*Megachile rotundata*), which is used for alfalfa seed production and sold for pollination of various crops, and the European honey bee (*Apis mellifera*), which is managed for hive products (honey, beeswax, propolis, etc.) and to help pollinate pollinator-dependent crops. Both species are dominant components of the bee communities in which they are managed, though little research has addressed their impacts within Colorado ecosystems. All of these species likely have impacts, though, that probably exist along a continuum driven by the sociality of the species and how they are managed (see Figure 2.39, a scale of risk from Russo et al. 2021).

Although little research has been done in Colorado, **non-native managed bees have been shown to have serious impacts on native bee populations, health, and communities around the country and globe**. European buff-tailed bumble bees (*Bombus terrestris*), which have been cultivated for greenhouse pollination, have been introduced into South America, where they have rapidly invaded (Fontúrbel et al. 2021), disrupted native bumble bee–host plant mutualisms (Chalcoff et al. 2022), introduced new parasites (Arbetman et al. 2013), and subsequently extirpated native bumble bee species from areas where they have escaped (Morales et al. 2013). Similarly, in North America, the cultivated eastern bumble bee (*Bombus impatiens*) has already been introduced or escaped outside of its native range in several western states and Canada (Looney et al. 2019), has already been implicated as a reservoir of infectious bee diseases (Sachman-Ruiz et al. 2015), and is anticipated to become problematic for the conservation of native western bumble bees. Moreover, the impacts of non-native plants and non-native pollinators could be synergistic. For example, one study in Boulder found that non-native honey bees preferred non-native flowers to native flowers, which could implicate honey bees in supporting the spread of non-native plants (Krend and Murphy 2003). More research, though, is needed to disentangle feedbacks between invasive plants and pollinators and their impacts on native species.

By far, the most widespread, abundant, and impactful species of non-native pollinator is the European honey bee. **Honey bees can be the most numerically dominant bees where they are managed and have**

Table 2.1. Colorado's Non-Native Bees

Colorado is home to at least 11 species of non-native bee, some of which were purposely brought to the US but now have feral populations. There are also several species that are likely to be found here in the coming years.

Family or Species	Notes on US and Colorado introductions, including date of arrival
Apidae	
Apis mellifera	1620. From Europe. Managed, but feral colonies present throughout North America.
Xylocopa virginica	2000. From the eastern US, but recently seen along the Front Range.
Colletidae	
Hylaeus leptocephalus	1900. From Europe. Introduced throughout the US and Colorado by 1911.
Hylaeus punctatus	1980. From Europe. Introduced to Colorado around 2010.
Hylaeus hyalinatus*	1990. From Europe. Introduced to northeast US, with potential to spread widely
Hylaeus communis*	2012. From Europe. Introduced to Canada, with potential to spread widely.
Halictidae	
Andrena wilkella	1900s. From Europe and Asia. Introduced to north central US; in Colorado since 2015.
Lasioglossum leucozonium*	1900s. From Europe and Asia. Introduced in central and eastern US, with potential to spread widely.
Megachilidae	
Anthidium manicatum	1960. From Europe, Asia, and N. Africa. Introduced across US; in Colorado since 2000.
Anthidium oblongatum	1990. From Europe, Asia, and N. Africa. Introduced in eastern US; in Colorado since 2009.
Megachile apicalis	1930. From Europe, Asia and North Africa. Introduced across the western states; in Colorado since 2014.
Megachile concinna	1940. From Africa. Reported from Colorado as far back as the 1950s.
Megachile rotundata	1920s. From Europe to China. Introduced throughout North America, now managed; in Colorado since the 1960s.
Megachile sculpturalis*	1997. From Asia. Introduced across eastern US and has spread west to Nebraska, Kansas, and Texas.
Osmia cornifrons	1960. From Asia. Introduced to pollinate tree fruit crops in the Northeast; in Colorado since 2014.

* Potentially already here or on its way

been shown not only to compete with native bees, but to spread honey bee diseases to native bee species (e.g., Alger et al. 2019), **to alter the structure and functionality of entire networks of native plant–pollinator interactions** (Valido et al. 2019), and **to displace native bees, altering pollination services to native plants** (Page and Williams 2023). In Colorado, little research has explored these mechanisms, but increasing interest in beekeeping has driven a surge in hobbyists and the impacts of a dramatic uptick in honey bee hives are concerning native pollinator researchers. Urban beekeeping, in particular, has been increasing in Colorado, driven by the "save the bees" campaign that gained momentum in the late-2000s in response to global colony losses experienced by beekeepers (C. Briles, personal communication). However, misconceptions surrounding the role of urban beekeeping in supporting both honey bee populations in

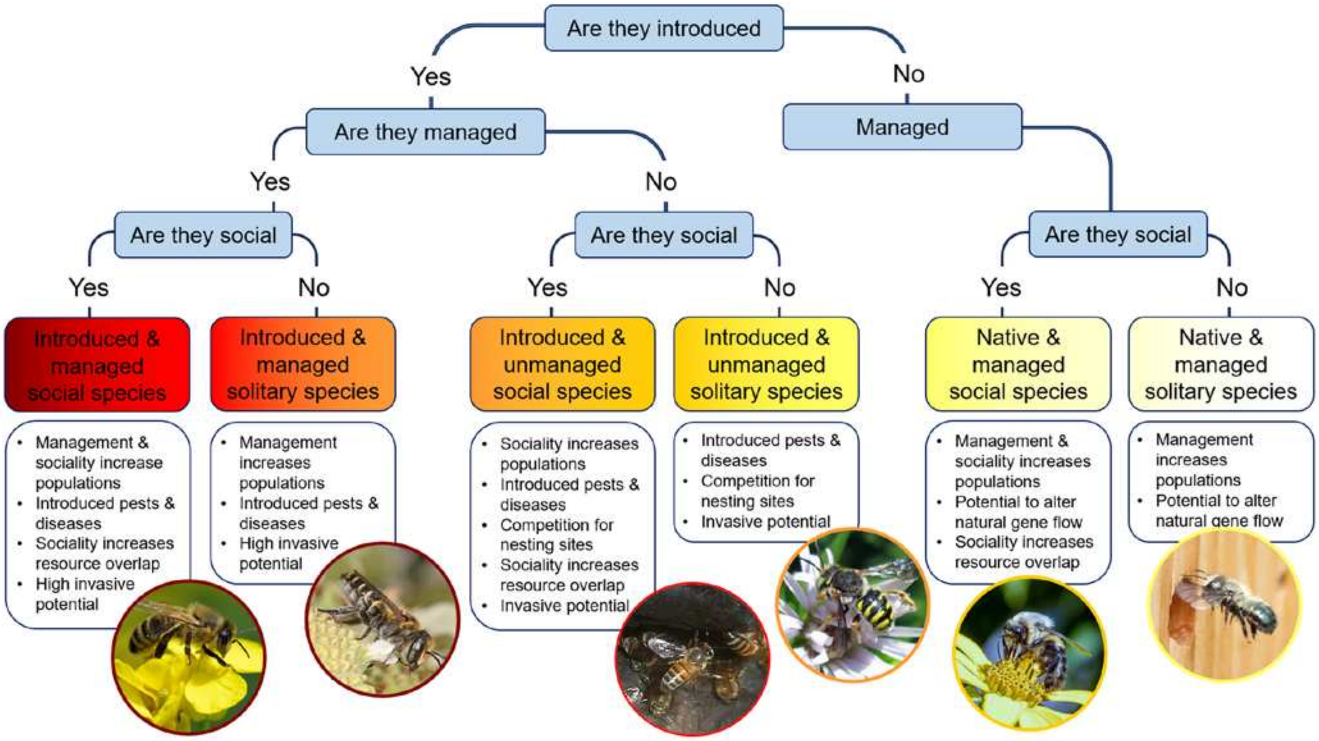


Figure 2.39. A conceptual approach to classifying risk of introduced bees, with yellow being less risk and red more risk to native pollinating insects. (Adapted from Russo et al 2021.) (Photos [l–r]: lifar, BY-SA 4.0; Jarble, BY-SA 2.0; JMK, BY-SA 4.0; Jacy Lucier, BY-SA 4.0; and Rhododendrites, BY-SA 4.0; and A. Carper.)

agriculture and native bee populations persist. For example, large honey bee populations in urban areas likely compete with native bees and other pollinators for resources and potentially spread diseases and parasites, posing a threat to native pollinators in urban landscapes (Egerer and Kowarik 2020). In Colorado, the registration and regulation of honey bee colonies are typically managed at the county or city level, if at all, with limited resources available to address the growing number of managed honey bee colonies and their associated impacts.

The issues surrounding managed honey bees are complex, but **a primary goal of management should be to inform beekeepers of their potential impacts, and to create strategies to reduce the negative impacts of managed honey bees** on native pollinating insects. For example, many local beekeeping clubs train and promote new beekeepers, contributing to the proliferation of urban honey bee colonies within Colorado, but not necessarily offering comprehensive training and mentorship, particularly concerning disease management, swarm control, or how to mitigate impacts on native pollinators. This represents a huge gap in honey bee management and likely a very impactful area of future need for statewide policy and leadership. State leadership could include the need for messaging that shifts the focus from supporting a single managed agricultural pollinator (i.e., honey bees) to emphasizing the importance of protecting native pollinators. Ultimately, leveraging the existing momentum and interest in honey bees could be a valuable strategy for promoting conservation efforts aimed at preserving native pollinating insects, and any efforts to engage with beekeepers should be open to the goals, interests, and needs of that community as well.

As research on the impacts of non-native bee pollinators, including honey bees, has grown, conservation organizations have taken notice and action. The Xerces Society has compiled an overview of the potential impacts of honey bees (Hatfield et al. 2018) and a recent petition by the Center for Biological Diversity

(2020) urges federal agencies to prioritize native bee conservation over commercial beehive production on federal lands, especially as commercial operations increasingly rely on such lands in support of the migratory pollination trade in honey bees (the transportation of honey bees around the country to support the pollination needs of farmers). However, **some of the needs of managed bees and wild bees are similar, and some evidence suggests that management could have positive impacts on both**. For example, in the High Plains of North Dakota, both honey production and wild bee abundance, diversity, and functional diversity increased with more grasslands, flowering crops, and other natural habitats in the landscape. Conversely, non-entomophilous crops such as corn and wheat were associated with decreased native bees and honey bee survival (Evans et al. 2018). This suggests that even in agriculturally intensive regions, dual management goals could potentially be achieved by diversifying agricultural systems, and creating more abundant and diverse floral resources in general. Overall, research on how best management practices that address the sustainability of different habitats or land uses for both native and managed bees, including estimates for the number or density of hives, are crucial gaps in our understanding of how to promote native pollinators and support sustainable honey bee production.

Non-native plants and pollinators are common in Colorado and are likely impacting native pollinating insects throughout the state. While invasive plants are displacing native wildflowers, there is some evidence that generalist pollinators can adapt to utilize the nectar and pollen of invasive species. The consequences of this resource use for pollinator communities is largely unknown. Additionally, limited evidence from Colorado has shown mixed results of invasive-plant removal when pollinator responses have been measured. More research is needed to understand how different methods of invasive-plant removal influence Colorado's pollinators. The impact of non-native pollinators on the native pollinating insects of Colorado is even less understood, though they are likely bringing competition and disease. The effects of managed honey bees in Colorado are particularly important to study, as it is known globally that honey bees can disrupt pollination networks and displace native bees, even where honey bees are native to a region. This research could inform management practices that support the health of both honey bees and native bees while mitigating the impacts of managed honey bees on native species.

2.3.9. Climate Change

Takeaways:

- Changes in Colorado's climate are impacting pollinating insects.
- Pollinators in Colorado's high-elevation environments (montane, subalpine, and alpine) and the plants that they pollinate are most at risk.
- Climate change is directly impacting Colorado's pollinators, through increased temperatures, which can interfere with insect development, and extreme events, like floods or frosts, which wipe out habitats and hostplants.
- Colorado's pollinators depend on flowers, which are being strongly impacted by climate change. Declining wildflower populations, as well as changes in the timing of flowering (phenology), are likely to have an even larger negative impact on pollinators than the direct effects of increasing temperatures.

Climate change is impacting ecosystems and natural resource management nationally and globally, with implications for all of biodiversity, including pollinators (Díaz et al. 2019; reviewed in Weiskopf et al. 2020). Subalpine and alpine environments are especially vulnerable to climate change because cold environments are more temperature sensitive (Ernakovich et al. 2014). In Colorado, the high-elevation habitats that are cherished by residents and visitors alike are showing changes in both plant and pollinator communities. Climate change can also increase the negative effects of agriculture and urbanization on insects, which are likely driving pollinator declines in the rest of the state. **Research in Colorado shows that climate change is interfering with the life cycle of some pollinators, changing where pollinator species live, and disrupting the interactions between wildflowers and their pollinators.** While very few studies have investigated potential ways to lessen the impacts of climate change on pollinators, knowing the ways that climate change is affecting Colorado's pollinators, particularly in the mountains, is an important first step for conservation and land management.

Research efforts evaluating climate-driven changes in the mountains of Colorado have focused on several different environments, which are commonly distinguished by elevation. In this section we'll focus on a few specific habitats. Montane habitats generally occur from 8,000 to 9,500 ft. (2,440 to 2,895 m), are drier and are dominated by ponderosa pines, Douglas-firs, and aspens. Climbing up in elevation, subalpine habitats, which generally occur from 9,500 to 11,500 ft. (2,895 to 3,505 m), have forests made up of Engelmann spruce and subalpine fir as well as wildflower meadows. Finally, alpine habitats, which generally occur over 11,500 ft. (3,505 m), are mostly open and free of trees, and made up of low-lying tundra plants. Most research addressing the effects of climate change on pollinators in Colorado has taken place in subalpine habitats.

Climate change can have both direct and indirect effects on pollinating insects. Aspects of climate change that can impact pollinators include an increase in extreme weather events, such as flooding, changes in the amount or timing of rain, snow, or frost, and temperature changes. These environmental factors can impact pollinators directly. A direct effect of warming climate, for example, could be driven by an insect's inability to tolerate higher temperatures. The same environmental factors can also have indirect effects, for example, by impacting another species which then impacts the pollinators. A warming climate could result in the loss of a sensitive wildflower species, for instance, which pollinators can no longer use for food. Such indirect effects can be complex, but likely play outsized roles in how climate change impacts pollinators. Below, we review the evidence of both direct and indirect effects of climate change on Colorado pollinating insects.

A**s climates warm, the risk of catastrophic storms and flooding increases** (Karl and Knight 1998; IPCC 2023) **and these events can have large impacts on pollinators**. This was evidenced between September 10 and 15, 2013, when the foothills surrounding Longmont were inundated with record-breaking rainfall, setting daily precipitation records including the all-time highest daily rainfall (9.08" [23 cm] on September 12, NOAA 2023), and resulting in catastrophic flooding. Prior to the flooding, in 2012, the CU Museum of Natural History had recorded the abundance and diversity of native bees along Longmont's St. Vrain Creek. This gave researchers a rare opportunity to measure the impacts of such extreme events on the pollinator community, leading to re-measurement efforts in 2014 and 2020. Between 2012 (pre-flood) and 2014 (post-flood), bee abundance along the creek declined by 24% and bee diversity declined by 19%. Sites along the St. Vrain Creek with higher degrees of flooding had 49% fewer bees overall than the average of all sites (Mullins 2021); more severe flooding caused a more negative impact on bees. By 2020 (7 years post-flood), bee abundance and diversity had both somewhat recovered, likely following extensive efforts to restore these habitats. Incorporating the potential impacts of riparian (riverside) management and restoration could therefore be an important target for pollinator conservation.

Figure 2.40. Climate change is leading to less snowpack, earlier snowmelt, and overall drier conditions in Colorado's mountains, posing risks to alpine and subalpine plants and the pollinating insects that depend on them. (Photo: Adrian Carper.)

The average temperature in Colorado has increased substantially in the last several decades and warming has directly affected Colorado's pollinators. Temperatures in the subalpine at RMBL, for example, rose by 0.4 ± 0.1°C (0.7 ± 0.2°F) per decade (1.6°C total [2.9°F]) between 1974 to 2012 (CaraDonna et al. 2014). All species have a range of temperatures within which their bodies function optimally, and outside of which, they face damage or death. For example, in a study in Arizona, the high-elevation, early season blueberry bee (*Osmia ribifloris*), which occurs throughout the mountains of Colorado, had increased death rates in experimental nest blocks that were darkened to increase the temperature within nests, mimicking future climate change-driven warming of nesting conditions (CaraDonna et al. 2018). This suggests that as the hottest days of summer become hotter, bees in nature may suffer higher death rates. Larvae (the immature form of bees) cannot move from their nests to find cooler temperatures, and so are particularly vulnerable.

The impacts of climate warming are also apparent in bee population measurements. Bumble bees, an important group of pollinators in high-elevation environments, are especially vulnerable to a changing climate and many scientists have studied the impacts of temperature change upon bumble bee populations. Using one of the largest bumble-bee datasets across North America and Europe, Soroye et al. (2020) found that the rising frequency of extreme heat is increasing local extinction of bumble bees, with species no longer found in areas too warm for them to persist. The most conservative models suggest that nearly half of all bumble bee species will have smaller ranges by 2050, while more extreme estimates suggest that up to 97% of species will decrease in their distribution. Though bumble bees can move to cooler habitats, this study showed that even latitudinal movement up to 6.2 miles (10 km) each year will not prevent these range contractions. Altitudinal movement of bumble bees has been documented near RMBL, by comparing their distributions over 33 years (Pyke et al. 2016). In regions with intense agriculture and areas in the western United States, including much of Colorado, bumble bee species are likely to experience even greater species losses from their historic ranges (Sirois-Delisle and Kerr 2018). Though not as well studied, other pollinators are likely to also experience declines and range shrinkage in response to climate warming. For example, warmer temperatures in the subalpine in Colorado also reduced abundances of comb-building bees (Pardee et al. 2022).

In the mountains of Colorado, changes in both temperature and precipitation combine to determine the snowpack, which has profound impacts on pollinating insects that only emerge for the season after the snow melts. Analyzing nine years of data on the entire bee community from montane and subalpine habitats at RMBL (including 67 different bee species), Stemkowski et al. (2020) found that community-wide bee emergence in the spring, peak abundance during the season, and their decline at the end of the season, were all driven primarily by the date of snowmelt, with bees emerging, peaking, and declining earlier in years with earlier snowmelt. Earlier dates of snowmelt were also the single biggest predictor of decreasing population growth rates of the Mormon fritillary (*Speyeria mormonia*) at RMBL, due to more common frost damage to caterpillars and to the wildflower the adults rely on for nectar that females need to make eggs (Boggs and Inouye 2012). For bees that spend the winter underground as prepupae or pupae (the life stage just before adulthood), the snowpack can act as an important insulator against subfreezing temperatures. In the subalpine at RMBL, in years with lower snowpack, bees that spend winter as larvae or pupae were less abundant. In highly sensitive areas, methods such as snow fences could potentially be used to increase snow accumulation over prime nesting habitat of these ground-nesting species, though such methods have never been tested.

Figure 2.41. Climate change is impacting the flowering plants in Colorado's subalpine and alpine, which in turn influences the pollinating insects that rely on these flowers. (Photo: KimonBerlin, CC BY SA 2.0.)

In addition to the direct effects that climate change has on pollinators, it also has concerning indirect effects on pollinators via the plants they feed upon. As pollinators depend on flowers, and **climate change has become the biggest driver of alpine plant communities in Colorado** (Inouye 2008; Inouye 2020), **the indirect impacts of changes in flower communities is likely one of the biggest factors mediating climate impacts on pollinating insects**. Over nearly 40 years, snowmelt in the subalpine at RMBL has shifted 3.5 days earlier per decade, on average. For flowering plants, their timing of emergence in the spring as well as the start and end of flowering has also shifted in response to snowmelt, though in ways that vary tremendously across different flower species (CaraDonna et al. 2014). Climate change-induced earlier snowmelt has been shown to reduce the population growth rate of subalpine flowers (Wadgymar et al. 2018). The negative impact of early snowmelt on plant populations does not, for at least some species, seem to be due to a lack of pollination (Campbell et al. 2022). Instead, earlier snowmelt has especially negative effects on plant species that flower soon after snowmelt, when temperatures are still low. The climate-driven shift in flowering date increases the risk of their flowers becoming damaged by frost (Inouye 2008; Gezon et al. 2016; Pardee et al. 2019), thus limiting their reproduction. The negative impacts of earlier snowmelt on plant populations therefore indirectly impacts pollinators by causing a shift in plant phenology and reduction in flowering of certain plant species.

Changes in precipitation are also negatively impacting plants and, indirectly, pollinators. For example, long-term data on the subalpine little sunflower, *Helianthella quinquevervis*, a very important floral resource for subalpine pollinators, suggest that drought over longer growing seasons is the primary driver of population declines (Iler et al. 2019), which likely constitute a huge loss of nectar and pollen resources for pollinators. Frost, the influence of which is tied to snowmelt timing, can kill all of the flower buds of *Helianthella* in some years, and this is becoming more common as a consequence of climate change (Inouye 2008). With longer drier summers, observed shifts in the distribution of flowers from one peak of bloom across the season to two peaks, one earlier and one later, could have negative implications for pollinators like bumble bees and also hummingbirds that depend on season-long floral resources (Aldridge et al. 2011).

Another big factor driving the indirect, flower-mediated effects of climate change on pollinating insects is whether plants and pollinators respond differently to changing environmental conditions. Researchers at RMBL have been studying these effects for the past 50 years and have provided good evidence that plants and their pollinators do indeed respond differently to changing climates. From 1974 to 2017, bumble bee species in habitats ranging from montane to alpine shifted nearly 820 ft. (250 m) higher in elevation on average (ranging from 240–1,411 ft. [73–430 m] higher per species) and emerged 14 days earlier, on average, at the start of the season, both in response to warming climates. Plants, in contrast, did not move upward over the same period, but instead flowered 47 days earlier, on average. The new flowering date was 33 days earlier than bumble bees emerged, reducing overlap between bumble bees and the flowers that they depend on (Pyke et al. 2016). Plant species that flower early in the season may experience reduced pollination, and resulting reduction in reproduction, in years with particularly early subalpine snowmelt (Thomson 2010). Climate change-induced shifts in the timing of pollinators and plants may therefore have negative consequences for both groups.

The mismatch in timing is driven by different limitations in pollinator and plant responses to changing climate. Bees, for example, are highly mobile and have the potential to quickly track environmental conditions by flying to new habitats or moving upward in elevation over a single season. Though some plant populations can move large distances over long time spans, the opportunity for substantial movement generally only comes once a generation, with the production of seeds. Alpine plants are mostly long-lived perennial species, which are slow to move to new habitats with better environmental conditions. In addition, alpine species typically don't have an opportunity to move up in altitude, since they are already on mountain tops. Instead, these plants alter when and how much they flower in response to environmental change. Through time, these mismatches in timing between plants and pollinators could have long-term effects on pollinating insects. For example, in one eight-year study (2009–2016), bumble bee abundances in subalpine meadows were driven primarily by the indirect effect of climate on flowers and less so by the direct effect of climate itself on bees (Ogilvie et al. 2017). For a diverse group of organisms in the subalpine environment at RMBL, including plants, insects, and vertebrates, climate variation was the biggest driver of life-cycle timing, with different types of species responding differently to climate impacts, some earlier and some later, driving mismatches between plants and animals through time (Prather et al. 2023). While there are examples of some pollinator groups who maintain synchrony, e.g., syrphids at RMBL (Iler et al. 2013), the indirect effects of altered timing on plant–pollinator interactions is likely one of the biggest drivers of pollinating insect communities.

As the relationships between plants and pollinators are disrupted, **pollinators with broader diets are appearing to be more resilient to these changes**. Specialist pollinators, such as those studied in montane and subalpine environments at RMBL, and especially those that emerge early in the season, experience the worst mismatch in timing with their flowers as a result of climate change (Stemkovski et al. 2023). Generalist pollinators, on the other hand, perhaps because they have a broader floral diet, are better able to tolerate climate-driven disturbance in plant communities. This has particularly been established in high-elevation environments, including in Colorado's subalpine (Resasco et al. 2021). This trend can lead to an increase in generalist species, as specialists are harder hit by changes (Resasco et al. 2021). Specialist pollinators are thus likely to be the most at risk as the climate continues to change. The increased resiliency of generalist pollinators, however, does give some hope for continuation of pollination services even given community-wide response to climate change.

Climate change may also impact pollination networks and therefore the pollination services provided to entire communities of plants. Resilient generalist pollinators may be able to buffer pollination networks, to some extent, against climate change. Local extinction of a few pollinator species may not result in community collapse, as generalist pollinators can still provide pollination to all plant species (e.g., Reseasco et al. 2021). However, plant pollination depends on the transfer of pollen from other flowers of the same species. How often pollinators travel between flowers of the same species, as opposed to other species, can influence plant reproduction. An experiment at RMBL showed that the experimental exclusions of one dominant bumble bee species within a subalpine community, which simulated the loss of this species, resulted in community-wide disruption of pollination networks and less transfer of species-appropriate pollen (Brosi and Briggs 2013), as was also shown in an earlier experiment (Inouye 1978). This means that species loss due to climate change, and resulting changes in pollination networks, may have far-reaching consequences for plant communities.

The movement of individual pollinating insect species in response to climate change can also result in indirect climate effects through altered interactions with other pollinators. Bumble bees, for instance, have small foraging areas, particularly at higher elevations. Individual bumble bees of some species can only travel 80–360 ft. (25–110 m) for food (Geib et al. 2015) and so may face high competition for flowers within this limited range. Altered pollinator distributions due to climate change could alter competition for shared flower resources. In response to a warming climate, ongoing research from across a wide elevational gradient on Pikes Peak (foothills to high alpine) suggests that five Colorado bumble bee species will move upwards into the alpine, where eleven species already reside. Overlap in bumble bee species traits like body size suggest that several bumble bees will experience increased competition for flowers in response to climate change-driven movement (Barthell and Resasco 2023). Increased pollinator competition, in combination with changes in plant communities, could have dramatic effects on pollination networks.

Though Colorado has hosted an impressive number of research studies on the impacts of climate change on pollinating insects, there is a great deal more work to do. High-elevation environments (especially the subalpine), which are particularly vulnerable, have received the most attention from researchers who are measuring the impacts of climate change. How to translate these findings into management plans in these mountain environments, however, is still unknown. Additionally, climate change is also likely to impact pollinators in the agricultural and urban parts of Colorado. Urban areas, due to their lack of vegetation, have elevated temperatures, which will mean even higher temperatures under climate warming. Lastly, most of this research has focused on bees, specifically bumble bees. Knowing how a greater range of individual species respond to changing climates, especially for species of conservation concern, could help identify strategies to mitigate climate impacts.

2.4. Scientific Conclusions

2.4.1. The State of Colorado's Native Pollinating Insects

From a comprehensive scientific perspective, the condition of Colorado's native pollinating insects is strong, but also precarious, given the unprecedented stresses that they face. Colorado has a large amount of public land as well as extensive private lands under conservation easements that are relatively protected and home to an incredible diversity of native pollinating insects. The very few studies that have evaluated long-term trends in native pollinators suggest that Colorado does indeed have many areas with relatively diverse and intact communities of pollinators. However, a great deal of evidence points to the fact that human-caused environmental change represents an overwhelming risk to our native pollinating insects. Land-use change has already driven habitat loss across the state and increasing agricultural intensification and urban development pose even greater risks to remaining habitats. Even in relatively pristine regions, such as the forests and mountains, native pollinators are experiencing stresses from climate change-induced ecological processes, such as fire, drought, and extreme weather. Exposure to introduced species and pesticides and pollution compound these stresses even further. These environmental changes have the potential to cause severe impacts to native pollinator health if the state is unable to implement management recommendations that can help mitigate their negative impacts. Luckily, research on how land managers can promote more healthy pollinating insect communities through management is growing and represents a promising avenue for the co-management of both human and ecological benefits. **The challenge going forward is determining how best to mitigate these impacts, and to develop appropriate goals, measures, and projected outcomes for management that incorporates native pollinators, as well as other ecosystem attributes, into a wide range of management strategies and their assessment.**

2.4.2. Gaps and Future Research

Takeaways:

- Climate change, habitat loss, and pesticides represent the biggest threats to native pollinating insects.
- The impacts of managed pollinators and non-native species represent the biggest gaps in our understanding of what impacts native pollinating insects.
- In order to determine the efficacy of conservation efforts and to understand nontarget impacts of management strategies, effects on pollinating insects must be measured.
- Long-term monitoring is the best tool for gauging how at risk Colorado's pollinating insects are.

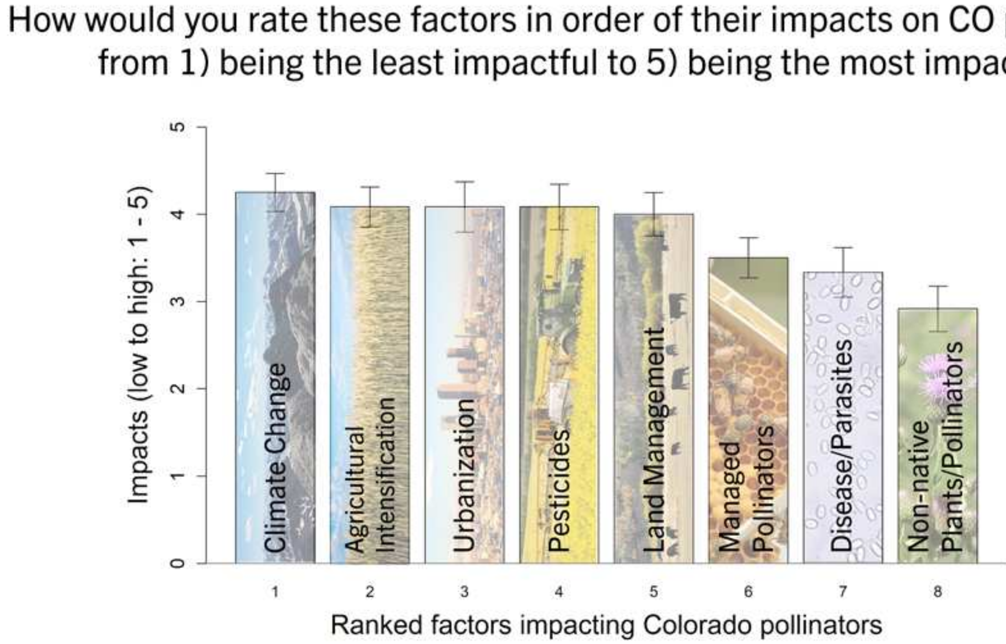
Although a great deal of research on native pollinating insects has been done in Colorado, many gaps still exist in both our scientific understanding of the mechanisms impacting pollinators, and how management practices contribute to, or could potentially mitigate, their impacts. In order to best characterize these gaps, we surveyed 12 researchers who study native pollinating insects within Colorado. **Results from their combined expert views suggest consensus that native pollinating insects are most impacted by climate change, then by land-use change from agricultural intensification and urbanization, and then pesticides**; however, concern of the impacts of management of grazing and forestry scored nearly as high. Intuitively, these concerns are driven by the factors for which we have the most data, and factors that scored lower, such as **managed pollinators and non-native plants and pollinators, represented the biggest gaps in our scientific understanding of their impacts**.

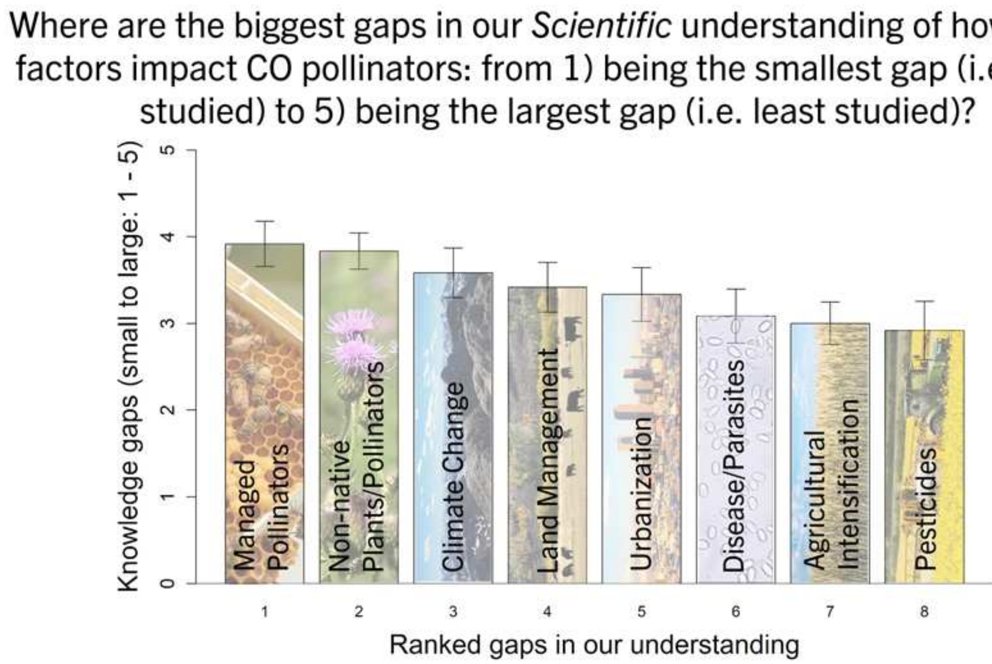
From a fundamental scientific perspective, there is still a need for basic research on pollinating insect biology, ecology, and distributions. **Many pollinating insect groups, such as beetles, wasps, and flies, remain understudied as pollinators.** For example, work in Colorado has been important for showing the particular importance of flies as pollinators in subalpine habitats (Kearns 1992) and more recent research was the first to examine how syrphid flies and the plants that they pollinate are responding to climate change (Iler et al. 2013). Flies, however, are still very understudied as pollinators in general (Inouye et al. 2015) and the impacts of land-use changes in Colorado on flies is mostly unknown.

Even within well-studied groups, such as bumble bees, there remains a lot to still discover. Male bumble bees at the RMBL, for example, are often overlooked as they do not specifically collect pollen to feed to young bumble bees. However, they still visit flowers to feed on nectar and can be very effective pollinators of alpine plants, even outnumbering female bumble bees in visits to some species, and contributing similar to pollination during visits (Ogilvie and Thomson 2015). However, most ecological studies still dismiss the role of male bees in plant–pollinator interactions. The role that traditionally understudied pollinators play in pollination remains a huge gap in our fundamental understanding of pollinating insects.

Moreover, the additional roles that pollinating insects play in entire ecosystems is likely an important area for future research. Pollinators contribute to other habitats and ecosystem services, through mechanisms that are less studied, but no doubt vitally important. Approximately 70% of the over 1,000 native bee species in Colorado, for instance, nest in burrows underground (Scott et al. 2011), and these ground nesting species contribute to soil biodiversity, health, and function, all while being impacted by management practices which impact soils, such as tillage, pollution, and pesticides (Christmann 2022). Understanding how different groups of pollinating insects affect ecosystems and how management practices impact them, is a huge gap in our mechanistic understanding of native pollinating insect ecology.

Figure 2.42. In a survey of Colorado pollinator researchers, respondents were asked to rank both known factors impacting pollinators and knowledge gaps. Climate change ranked highest for known impacts, while managed pollinators were the biggest knowledge gap.





The importance of different pollinator species to rare and imperiled plants is a basic ecological level of understanding still lacking in order to promote both. Since before the turn of the twenty-first century, Colorado pollinating insect researchers have stressed the need to develop better understanding of how plants and pollinators interact, and how basic and applied research can help guide revision of management policies and practices which impact them (Kearns et al. 1998). Most imperiled flowering plants likely depend on pollinating insects to some degree. For example, in a study of potential pollinators to seven imperiled plant species of the middle Arkansas Valley by the Colorado Natural Heritage Program (CNHP), researchers found that all seven species of globally imperiled endemic plant species (occurring only in Colorado) were visited by insect pollinators, and likely depended to some degree on them for reproduction (Panjabi 2004). Little is known about the risk of co-extinction of insect species within communities (where the extinction of one species leads to the extinction of another interacting species) (Kehoe et al. 2021), or the role that plants play in insect extinctions. Connecting pollinator and plant researchers with managers and conservationists could help co-develop research to inform better conservation practices that benefit plants and their pollinators.

The distributions of most pollinator species in Colorado are also poorly understood. The majority of pollinator sampling in Colorado has occurred on the Front Range and **significant data gaps exist on the Eastern Plains and in other rural parts of the state**. More complete species distributions will allow researchers to understand which species might be impacted by land-management issues in various ecosystems in the state. These data are also critical for future monitoring projects and to establish baselines in order to determine if species are declining

A huge frontier in the conservation and management of pollinators and the plants that depend on them lies in Colorado's mountain and alpine environments. These habitats are likely some of the most impacted by climate change, and therefore, of the most conservation concern, given how plants and pollinators are stressed by changes in seasonality, elevation, precipitation, and non-native species (reviewed in Inouye 2020). The impacts of altered snow regimes in alpine tundra represent a huge gap in our understanding of climate change-driven impacts on plants and pollinators (Rixen et al. 2022). Targeted studies and efforts to protect and restore alpine plant communities could help our understanding of how to mitigate the negative direct effect of climate change on high-alpine pollinators. Data on which plant species are most closely tracking the timing of pollinators, bloom during a time of the season when flowers are scarce, or are most important to threatened pollinators, could prove crucial to determining where to focus plant-conservation efforts in order to maximize benefit to pollinators.

Although most research has focused on floral resources for pollinators, much less has quantified or explored the importance of non-floral resources (e.g., nesting sites, materials, perfumes, etc. [Requier and Leonhardt 2020]). **Nesting resources in particular, could be an important driver of environmental impacts, but also a valuable opportunity to create positive conservation impacts**. For example, with nearly a third of the state's bee species nesting in cavities in wood or pithy stems, research on how to manage woody materials in our forests to balance multiple goals (e.g., forestry, fire, and pollinators) could help better mitigate any potential impacts of management on pollinators. Similarly, a handful of studies have shown correlations between ground-nesting bees and different environmental drivers. Research on the mechanisms responsible for those impacts on ground nesting species would help better inform how we manage agricultural, grazed, or urban landscapes in order to protect ground-nesting species.

Though we know that pesticides are a threat to pollinators worldwide, **the exposure and susceptibility of pollinators to pesticides within Colorado, and the ecosystem-wide impacts of pesticide use, are areas in need of more research**. This is especially important in urban areas, where there is very little regulation of where, when, and how most pesticides are used, as well as who is using them. The use of herbicides for conservation goals in Colorado is another area that could benefit from measurement of the impacts on pollinators. Moreover, studies on the synergistic effects of pesticides and other stressors are needed to explore how **the interaction of multiple stressors can have even greater impacts on native pollinating insects than would be expected if adding the effects of each factor**. In a global synthesis of bee declines and their causes, researchers suggested that the combined and interactive stresses of pesticides, disease, and lack of floral resources, have driven declines in both managed and wild bees. To counter these impacts, the researchers suggested that managers need to address both the underlying causative agents (such as by reducing pesticide use or planting more flowers) as well as monitor the efficacy of management practices and policies (Goulson et al. 2015). More studies that isolate the mechanisms driving the impacts of land-use change on pollinators while also considering the interaction of multiple mechanisms in a given ecosystem, though quite complex to execute, would be extremely valuable. Research that tackles these interactions within the context of specific land-management strategies would be invaluable for future conservation efforts.

According to researchers, **the impacts of managed pollinators (including honey bees) and non-native pollinator and plant species on native pollinating insects in Colorado represent the largest gaps in understanding of the health of Colorado's pollinators**. In particular, the effects of competition between native and non-native species for floral and nesting resources is unknown. This information, paired with better tracking of the abundance of managed pollinators, is needed to inform management of these non-native species to promote optimal health for both managed and wild pollinating insects. For non-native plants, it is important to evaluate the practices associated with invasive plant removal for impacts on pollinator communities. While it is clear that healthy native plant communities best promote native pollinators, plant removal practices, as well as restoration practices, can have suboptimal results if pollinators are not considered.

There is a great need to understand better how land-management practices are impacting Colorado's pollinating insects. This includes measuring the efficacy of practices that are aimed at conservation and investigating nontarget impacts of other management practices that may be influencing pollinators. While floral resources are crucial for pollinators, measuring plant communities alone is not enough to ensure that conservation practices are actually benefiting pollinators, which may be more sensitive to environmental factors (van Klink et al. 2015; Wang and Tang 2019) and may be strongly influenced by nesting resources, as discussed above. Actual measurement of pollinator responses to management can also reveal unintended impacts of particular practices. For example, as discussed in Section 2.3.6 Forests and Fire, while thinning has the potential to benefit pollinators by improving floral resources, there is also an unexplored potential for negative impacts through soil compaction from machinery and reduction in nesting materials through the removal of deadwood. Nontarget effects of management practices on pollinators may be common. In this review, we also discussed the potential impacts of the removal of invasive plants that are utilized by pollinators and the potential toxicity to pollinators of herbicides used for invasive-plant control. There may also, however, be positive nontarget effects of management, such as improvement of pollinator habitat through low-intensity grazing in the Eastern Plains, which could be leveraged to provide co-benefits to pollinators if better understood. Designing, implementing, and sharing collaborative research on the systemic impacts of management or mitigation efforts would be the most impactful for creating the most well-informed management and conservation practices.

Ultimately, the future of pollinating insect research in Colorado relies on continued support for research across institutions, agencies, and other organizations. For example, national interest in pollinator declines has led to coordinated monitoring efforts to track native bees across the United States, and a push to develop methods, models, and assessments for pollinator declines at national scales (Woodard et al. 2020). Many members of the research community are already engaged with these efforts, but to our knowledge, have not engaged with the State of Colorado on those efforts. This could be especially important, given the need for long-term monitoring and the constraints that field researchers face while trying to conduct uninterrupted long-term studies (Inouye et al. 2020). These types of studies are the best tool we have to track changes in pollinating-insect communities, which is vital to understand how at risk our pollinators are to human-caused environmental change.

Photo: Xerces Society / Carly Hirschmann

Section 3. Conservation Practices for Pollinating Insects and Their Habitats

3.1. General Considerations for Conservation & Management

At the heart of a healthy environment are pollinators, animals that move pollen among flowers, ensuring that plants can form seeds and fruits. In addition to visiting a vast range of native plants, this includes more than one hundred crop plants, such as apples, peaches, tomatoes, squash, and flax. The economic value of this ecosystem service in the United States alone is estimated to be approximately $16 billion per year (Calderone 2012; Rader et al. 2016; Khalifa et al. 2021). Beyond pollination, many ground-nesting pollinator species, such as mining bees (*Andrena* spp.), also play crucial roles in soil movement, allowing necessary water, air, and nutrients to reach plant roots and reducing erosion. Others, such as syrphid flies, will feast upon soft-bodied pests (e.g., aphids) as larvae, mitigating damage to plants. The services these keystone species provide are vital to the health of all of our environments.

Figure 3.1. Native grasses and wildflowers growing in the shortgrass prairie of the USDA's Central Plains Experimental Range near Nunn, Colorado. (Photo: Mary Ashby, USDA.)

Figure 3.2. A syrphid fly foraging on a *Dugaldia* flower. This fly is an excellent mimic of a worker bumble bee. (Photo: David Inouye.)

In Colorado alone, there are over 1,000 native bee species (Scott et al. 2011) and thousands of other native pollinating insects, such as butterflies, moths, syrphid flies, and more. Each has its own unique phenology, range, life-history strategy, and floral and habitat requirements. Many native bees are considered generalist species with broad geographic ranges and assorted phenologies. These pollinators often forage on a wide variety of flowering plants and can emerge in late-March and remain active until mid-November (Scott et al. 2011). A few bee species are considered extreme specialists with narrow geographic ranges, diet breadth, and phenologies (Minckley et al. 2013; Wilson and Messinger Carril 2015).

The complex phenology of native pollinator communities can vary widely across the landscape, such that sites even within a few miles of one another can be quite distinct (Fleishman et al. 1999; Kimoto et al. 2012a, 2012b; McIver and Macke 2014; DeBano et al. 2016). Therefore, prescribing recommendations that are ideal for all pollinators in all places is impossible. Successful management for pollinators should be implemented on a site-specific basis. Still, there are many general considerations that can benefit pollinators in most situations. The following recommendations apply to most management situations and are generally helpful approaches to consider for the conservation of pollinator communities overall.

3.1.1. Management, Policy, and Practice

In the context of pollinator conservation:

- **Management** involves the deliberate and strategic implementation of measures to safeguard and enhance the health and abundance of pollinators and their habitats.
- **Policy** refers to a structured set of rules, guidelines, and legislation established by governments and organizations at various levels, aimed at regulating and promoting actions that protect and support pollinators and their habitats. This creates a framework for coordinated efforts to address the complex challenges facing pollinators.
- **Practice** encompasses the tangible actions and strategies that individuals, communities, and organizations employ to contribute directly to the well-being and preservation of pollinators and their ecosystems.

In combination, these principles promote the creation and maintenance of diverse and pollinator-friendly habitats, support native plant species, reduce the use of pesticides, and expand education, outreach, and the collaboration between government agencies, nonprofits, farmers, and communities to address the threats posed by habitat loss, disease, and environmental stressors. Successful implementation will ultimately support pollinators and the broader benefits they provide to agriculture, biodiversity, and the environment.

3.1.2. Identify Important Pollinator Habitat (Forage [Floral] Resources, Nesting & Overwintering Sites, Reproduction Sites)

The first step in pollinator conservation is to recognize and protect existing pollinator habitat. Just like other animals, pollinators need food, water, shelter, and space to thrive. The amount and quality of natural habitat is intrinsically linked to pollinator population strength and health.

High-quality pollinator habitat provides:

- Food: nectar, pollen, and larval host plants
- Shelter, nesting, and overwintering sites
- Protection from pesticides

Additionally, at the landscape level, habitat connectivity is necessary for pollinator dispersal and migration.

Food Sources

Flowering plants provide the primary food sources for most adult pollinators in the form of nectar, a sugary fluid secreted by flowers that can contain amino acids and other dietary requirements. Bee larvae derive their primary nutrition by consuming pollen and nectar purposefully collected by their parent(s), whereas butterfly and moth larvae—caterpillars—require host plants such as forbs, grasses, shrubs, or trees to eat. For example, host plants of the western tiger swallowtail (*Papilio rutulus*) include willow and cottonwood, Colorado hairstreak (*Hypaurotis crysalus*) caterpillars feed on Gambel oaks (*Quercus gambelii*), and juniper hairstreak (*Callophrys gryneus*) caterpillars eat junipers (*Juniperus* spp.). Pay particular attention to native plants, as native pollinators are well adapted to feed on these species. Some pollinators, such as syrphid flies, have predatory larvae that hunt small insects and arthropods (some will also feed upon pollen).

To ensure adequate food sources for pollinator populations:

- **Include a minimum of three different native species blooming at any point during the growing season.** When selecting floral species, aim for a diverse range of flower structures, shapes, colors, sizes, and flowering phenologies. These differences in the physical characteristics of blooms will create several niches to reflect the wide diversity of pollinator foraging preferences. In Colorado, some generalist species can emerge as early as March and remain active until as late as November, so planting species that bloom in the early and late seasons can be highly beneficial.
- **Establish a diverse stand of native larval host plant food sources and consider the specific requirements of different pollinator species.** Some butterfly and moth caterpillars are adapted to feed on specific plant species, though many are capable of foraging on a range of related hosts. Planting several species of wildflowers (asters, milkweeds, legumes, etc.), perennial bunch grasses, sedges, trees (oaks, willows, wild cherries, etc.), and shrubs (rabbitbrush, currants, etc.) will ensure that caterpillars can meet their nutritional needs.

Shelter, Nesting, & Overwintering

Taking shelter, building a nest, and surviving the winter are all crucial aspects of the life history of pollinators.

To ensure adequate shelter, nesting, and overwintering sites:

- **Leave permanent woody, hollow, or pithy-stemmed vegetation standing in the fall and leaf litter and plant debris on the ground.** Many pollinators, such as solitary bees and certain wasp species, require cavities or hollow stems to build their nests. These cavities provide safe and protected spaces for their offspring. Ground litter, such as fallen leaves and other plant debris, provides insulation and protection against harsh winter conditions for overwintering pollinators until the next growing season when they become active again.
- **Maintain some naturally occurring bare ground.** Some ground-nesting pollinators require access to bare ground to excavate tunnels and build their nests. These tunnels provide pollinators with important protection from weather and predators during their vulnerable larval stage. Additionally, many pollinators, including butterflies and solitary bees, need access to warm, sunlit areas for basking and thermoregulation. Bare ground, especially in sunny spots, can serve as a heat-absorbing surface where these insects can warm themselves.
- **Avoid mowing, burning, or grazing the entire area; leave refugia.** Pollinators rely on diverse and undisturbed habitats for nesting, foraging, and reproduction. Mowing, burning, or grazing the entire area to the ground as an annual practice can destroy essential pollinator habitat, including nesting

- sites, food sources, and shelter. If pollinator species are present in an area that is subjected to intense mowing, burning, or grazing, especially during a vulnerable life stage, they will likely not survive.
- **Recognize the potential of areas for being good habitat.** Woodland margins, riparian areas, utility easements, road edges, conservation areas, and unused land around sports fields and maintenance buildings can all be valuable habitat for native pollinators. Even small parks will have room for flowers, caterpillar host plants, or nesting sites. A single site may provide one or more of these important components, but together they will greatly benefit and improve habitat for native pollinators.

3.1.3. Create Heterogeneity & Connectivity in Plant Communities & Provide Refuge for Pollinators

Landscape heterogeneity promotes diversity in vegetation and ecosystem structure. This can be highly beneficial to pollinator species, providing a diversity of plants and vegetation structure to support the differing life cycle needs of a diversity of pollinators. Habitat connectivity minimizes the distance a pollinator must travel to find food, build nests, find mates, and recolonize an area after a disturbance. The degree to which connectivity affects pollinators depends largely on the species. Some species, such as the monarch butterfly, will travel hundreds to thousands of miles in their lifetime, while other species will only reach a few hundred feet from where they hatched. Though the mobility of species can differ, whether at a small scale or much larger, well-connected habitats are vital to pollinator movement and conservation.

When various land management activities (e.g., burning, mowing, or grazing) will result in ongoing disturbance to an area, establish separate zones where the management activity can occur across the site over a multiyear cycle to retain undisturbed refugia "safety-zones" from which pollinators can disperse back into the surrounding habitat as it recovers. For example, leaving even a small portion of a field unmowed can provide an important undisturbed place for pollinators to persist. The pollinators in such a refugium can then spread back into the mowed areas when it is safe to do so. Without these refugia, there is a much greater risk of substantially damaging pollinator populations and extending the time it can take for reestablishment.

To maintain connectivity, heterogeneity and refugia:

- **Limit single management actions (such as mowing) to one third of the total habitat area in a single year.** Within the treatment area, consider leaving small untreated patches (e.g., areas skipped by mowing). This fragmented management strategy will promote heterogeneity within the landscape and create micro-refuges for pollinators. If the one-third rule is unfeasible, dedicate a few small patches as "disturbance-free zones."
- **Establish larger continuous patches of habitat.** Larger continuous patches of habitat also typically support a greater diversity of plant species, offering more food sources (nectar, pollen, and host plants) for pollinators throughout the year. Larger habitat areas are also more resilient to environmental stressors like drought, floods, and fire.
- **Provide corridors, even narrow ones, between habitat patches.** Corridors connect fragmented habitat patches, allowing pollinators to move between isolated areas. These connections are vital for maintaining gene flow and genetic diversity among pollinator populations and ensuring resilience to environmental changes and disease.

3.1.4. Invasive & Non-Native Plant & Insect Implications

Noxious weeds and invasive plant species can cause economic, public health, and ecological damage. Invasive plants lack natural enemies to limit their reproduction and spread (Cronk and Fuller 1995; Westbrooks 1998) and can significantly alter plant community composition, ecosystem processes, soil chemistry, and fire regimes, as well as reduce the abundance and diversity of pollinators and other herbivorous insects (Hopwood 2008; Zuefle et al. 2008; Burghardt et al. 2009; Tallamy and Shropshire 2009; Hanula and Horn 2011; Fiedler et al. 2012).

While some native pollinators are certainly capable of foraging upon invasive plants (e.g., non-native thistles are attractive to bumble bees and butterflies), several studies have shown that native pollinators strongly prefer foraging on native vegetation compared to non-native plant species (Hopwood 2008; Burghardt et al. 2009; Wu et al. 2009; Williams et al. 2011; Chrobock et al. 2013; Morandin and Kremen 2013; Ritchie et al. 2016). Invasive plants often provide floral resources only for generalist pollinators (Aizen et al. 2008), reduce habitat for specialist pollinators (Traveset and Richardson 2006), and may facilitate the establishment of non-native pollinators (Morales and Aizen 2002).

To reduce the harm of invasive and non-native plants and pests:

- **Monitor, manage, and avoid planting noxious, invasive, and non-native plants.** These plants can outcompete native plants and significantly disrupt natural habitats and ecosystem functioning. They often grow vigorously and crowd out native wildflowers that are crucial nectar and pollen sources for pollinators or that provide shelter or overwintering habitat. For example, smooth brome (*Bromus inermis*) can transform diverse grasslands into near monocultures over time, and can be very difficult to remove once its fibrous root systems are well established. Blooming species may offer nectar and pollen, but their timing and availability may not align with the life cycles and foraging patterns of native pollinators. This can disrupt the relationship between pollinators and their preferred native plant species and lead to a loss of essential nutrition.
- **Monitor and manage, and avoid spreading, invasive insect species.** Invasive insects can compete with native pollinators for limited resources, such as nectar and pollen from native plants. This competition can lead to food scarcity and increased stress on native pollinators. Some invasive insect species may prey on native pollinators or their larvae or compete with native pollinators for nesting sites and other resources. Others can serve as vectors for diseases that can affect both pollinators and the plants they visit.

Noxious Weed: Any plant designated as injurious to public health, agriculture, recreation, wildlife, or property by federal, state, or county government (Sheley et al. 1999).

Invasive Plant Species: Species that are defined by all of the following characteristics:

- Not native to the area of interest;
- Able to establish, persist, and spread (i.E., Naturalize); and
- Recognized to cause or potentially cause economic, human health, and/or ecological damage.

Categorization of invasive species is subjective, generally not legally binding, and determined at various geographic scales.

Native: Species that are indigenous to a region, i.e., those that occurred in an area for a prolonged period in the past.

3.1.5. Factoring in Managed Pollinators (European Honey Bee & Others)

Managed pollinators (European honey bees [*Apis mellifera*] and commercially reared bumble bees [*Bombus* spp.]) are undoubtedly important for the pollination of many important agricultural crops, such as apples, melons, and alfalfa (Morse and Calderon 2000). The United States honey production industry is also notable, bringing in over $371 million in 2022 (Shahbandeh 2023). However, as more areas of natural habitat are converted to agricultural and suburban uses, the pressures to use parks and other natural areas for placing honey bee hives are increasing. Honey bees heavily recruit foragers to highly rewarding flower patches, often strongly competing with and sometimes outcompeting wild pollinator species for necessary nutrition (Aizen et al. 2008; Giannini et al. 2015; Torné-Noguera et al. 2016). One estimate of resource use by honey bees found that a standard apiary with forty hives removes pollen that would otherwise support the development of four million wild bees (Cane and Tepedino 2017). The competition from honey bees can reduce wild pollinator visitation to native plants, reducing pollination and plant reproduction (Goulson 2003; Magrach et al. 2017).

Commercially reared honey bees and bumble bees are also capable of transmitting pathogens to native species through improper colony management and interactions on shared flowers (Singh et al. 2010; Furst et al. 2014). This can be particularly devastating to vulnerable native populations. Currently, honey bees are not endangered nor at risk of extinction. There are millions of hives across the world, and globally speaking, this number is stable or increasing each year (Phiri et al. 2022).

To care for managed pollinators and support native pollinators:

- **Monitor and perhaps limit the introduction of managed pollinators such as the European honey bee and commercial bumble bee hives.** While managed pollinators can be valuable for agriculture, it's essential to use them thoughtfully and in conjunction with efforts to protect and support native pollinator species. Caution should be taken when considering the placement of honey bee hives or other managed bees in or near habitat, especially habitat that supports imperiled or listed pollinator species.
- **Ensure responsible hive management practices to limit competition with native pollinators and the spread of pathogens.** Managed pollinators can compete with native pollinators for limited resources, including nectar and pollen from native plants, and spread diseases and parasites to native pollinators. Commercial honey bee hives, in particular, can serve as reservoirs for diseases that can have devastating impacts on wild bee populations. Regular inspections and treatments of honey bee hives will limit negative effects on nearby native pollinators.
- **Avoid the use of commercial bumble bee colonies in fields and allowing escapees from greenhouses.** Similar to honey bees, commercial bumble bee colonies can compete and breed with native pollinators and spread diseases (Colla et al. 2006; Kraus et al. 2011; Murray et al. 2013). In contained greenhouse settings, managed bumble bees can be a very successful pollination tool. However, their use in fields is likely more damaging to native pollinators than useful in crop pollination. Screening vents and entrance netting can significantly reduce the risk of managed bumble bees escaping from a greenhouse setting (Goka 2010; Evans 2017).

3.1.6. Consider How Management Interacts with Natural Stressors to Affect Pollinators (Climate Change, Drought, Extreme Weather Events, Extreme Wildfires, Other Disturbances)

Mismatches in temporal, spatial, morphological, and physiological interdependencies may obstruct vital interactions between pollinators and their floral hosts (Memmott et al. 2007; Hegland et al. 2009; Schweiger et al. 2010). This can alter pollinator activity, population dynamics, and phenology, sometimes even leading to extinction events (Stone and Willmer 1989; Parmesan et al. 1999; Thomas et al. 2001; Williams et al. 2007; Memmott et al. 2007; Hegland et al. 2009; Potts et al. 2010). Rare and imperiled pollinator species often have more specialized climatic niches and may experience heightened climatic impacts (Williams et al. 2007; Schweiger et al. 2010).

An example of a mismatch that could occur is if a drought severely suppresses wildflower blooms during the growing season, and then heavy grazing may further stress pollinators' ability to find sufficient nectar and pollen. In this scenario, reducing grazing pressure through adjusting timing, duration, and intensity could help minimize the effects of interacting stressors. Additionally, focusing conservation efforts on high-value pollinator habitat and the establishment of resilient and drought-resistant native plant communities will yield the most effective results to mitigate the negative interactions of stressors.

Figure 3.3. The Spring Creek Wildfire, near La Veta, Colorado, burned over 108,000 acres (43,700 ha) in 2018. (Photo: Tomi Price.)

To address how management actions can interact with natural stressors:

- **Recognize the impact of climate change, drought, extreme weather events, wildfires, and other disturbances on pollinator populations.** Climate change and extreme weather events can disrupt their life cycles, foraging patterns, and reproductive behaviors, making pollinators more vulnerable to population declines.
- **Mitigate stressors to enhance pollinator resilience.** By enhancing pollinator resilience, we contribute to the preservation of plant biodiversity, which is essential for healthy ecosystems and wildlife habitat, as well as agriculture and the production of fruits, vegetables, and other crops. Consider climatic factors, such as extreme weather events and droughts or floods, in management decision making. If an environment is under abnormal amounts of stress, limit high-disturbance management activities such as heavy mowing and grazing.

3.1.7. Time Management Activities to Minimize Negative Impacts on Pollinators

The available information about native pollinator phenology is limited, as pollinator phenology can vary from year to year, and site to site due to weather events, microclimate conditions, and shifting climate patterns (Kudo and Cooper 2019). Still, it is very important to consider when and where pollinators are and their life stages when planning management actions, as certain practices can be harmful to pollinators during their more vulnerable life stages (e.g., breeding). If the known host plant or special habitat feature (e.g., sloped sandy soil for a ground-nesting bee species) of an imperiled pollinator species is present within the known range of that species, there is a chance that the pollinator is also there and that certain management actions could result in direct mortality. If possible, surveying host plants and habitat features for pollinators before proceeding with management can be beneficial.

To time management actions better for pollinators:

- **Observe and document site-specific vegetation and pollinator populations.** This provides critical information for conservation and management planning.
- **Use a targeted vegetation management approach.** Using site-specific and species-specific vegetation management techniques enables the selection and promotion of native plant species known to be particularly attractive and beneficial to native pollinators and encourages the enhancement of specific habitat features. This helps to conserve plant sources, staff capacity, and funding.
- **Schedule land-management activities during periods of low pollinator activity.** For example, avoid mowing, spraying pesticides, or otherwise disturbing host plants and habitat features during active foraging and nesting timeframes.

Figure 3.4 (next page) offers broad guidance on when native bees are less likely to be affected by management such as maintenance activities, grazing, or mowing. However, note that bees that nest above ground (including some bumble bees) may be sensitive to management year-round.

3.1.8. Adaptive Management Framework

When evaluating pollinator conservation strategies, it is important to consider that the responses of pollinators to many management activities in Colorado or even in the West are understudied. Given the incomplete knowledge we currently have, adaptive management strategies are important for successful pollinator conservation efforts. Adaptive management is the iterative process of decision-making that uses existing information and science to inform decision making, acknowledges uncertainties, and encourages a balance of short- and long-term goals. Monitoring and documenting the responses of vegetation and pollinator species to the applied management strategies will allow for well-informed adjustments. Management plans need to be regularly revisited and adapted as needed based on what is learned to address future, changing conditions.

To manage adaptively:

- Continuously monitor, assess, and document vegetation and pollinator responses to management strategies.
- Be willing to adapt and refine management plans and future actions based on observations and changing conditions.

Figure 3.4: Recommended Management Timing for Native Bees in Western North America.

(Based on above- and below-ground nesting bee activity by genera and bumble bee activity by species)

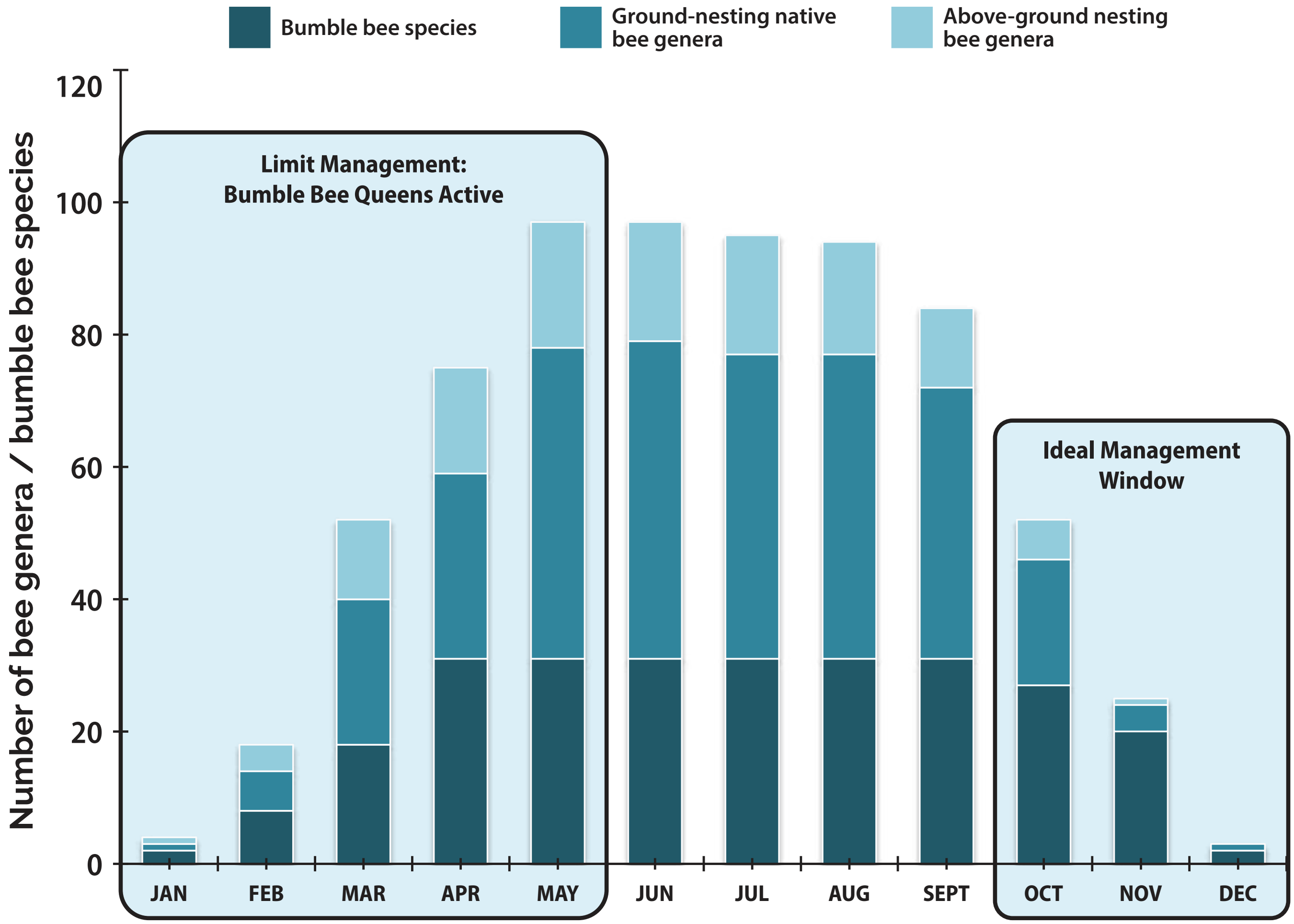


Figure 3.4. Recommended periods for land management activities to minimize negative impacts on native bees in western North America. (Activity of bumble bees is based on species-level information and on genera level for other native bees.)

3.2. Pollinator Conservation Management Practices

3.2.1. Conservation on Agricultural Crop Land

Increased intensity of farming is considered to be a factor contributing to the decline of some pollinators (Kremen et al. 2004; Potts et al. 2010). The reduction and fragmentation of uncropped areas on farms, as well as plantings of crops that lack floral diversity, can limit habitat available to pollinators on farms, and the lack of resources in intensely managed agricultural landscapes reduces pollinator diversity (Carvell et al. 2006). Colorado state agencies rarely have control over cropland practices, and as such we did not include specific questions about cropland practices in our surveys and interviews with state agency staff. However, recognizing that there are programs within agencies that center on conservation practices on working lands (e.g., Corners for Conservation), and that producers may be lessees of state lands, we are including an overview here of practices on croplands that can support pollinators.

Colorado produces a diversity of field, fruit, and vegetable crops, and many are dependent upon pollinators to transfer pollen between blossoms in order to set fruit. Pollination influences the quality of the fruit as well as overall yield; inadequate pollination can reduce the size and shape of the fruit and can reduce storage quality. For example, pollinators are crucial to the production of peaches and sunflowers, two insect-pollinated crops worth $33.9 million and $9.1 million respectively (NASS 2022a).

It can be beneficial for growers to consider the needs of pollinators in their farm management and on-farm conservation practices because these insects provide a helpful role in crop pollination, increasing yields and farm profit. Unmanaged, wild pollinators can contribute significantly to crop pollination (Garibaldi et al. 2013), supplementing pollination by managed honey bees, or, depending on the situation, providing all the pollination needs of a particular crop (e.g., Winfree et al. 2007). Wild bees can also increase fruit set in some crops in which honey bees are less effective (Mallinger and Gratton 2015).

Creating habitat such as hedgerows or field borders on farms can increase wild pollinators in agricultural landscapes and their contributions to crop pollination (Morandin and Kremen 2013; Blaauw and Isaacs 2014). Changes in farm practices can also better support pollinators by increasing food and nesting or overwintering resources for pollinators, or by protecting habitat from pesticides. Temporary habitat such as cover crops or insectary strips can increase bee and hoverfly abundance (Ellis and Barbercheck 2015; Jonsson et al. 2015). Minimizing tillage can benefit ground-nesting bees that nest within crop fields (Shuler et al. 2005; Sardinas et al. 2016; Ullmann et al. 2016). Altering pest management practices to reduce risks to pollinators can also influence pollinator abundance and richness (Brittain et al. 2010; Park et al. 2015), given that pesticides can contribute to pollinator declines (Kevan 1975; Alston et al. 2007; Rundlof et al. 2015; Stanley et al. 2015; Woodcock et al. 2016; Tamburini et al. 2021).

Figure 3.5. Farm in Boulder County with a flowering field border to provide habitat for pollinators and beneficial insects. (Photo: Jennifer Hopwood, Xerces Society.)

Recommendations for Cropland Practices

Create Pollinator Habitat Outside of Cropped Areas on Farms

On-farm habitat can support a diversity of pollinators and other beneficial species such as predators and parasitoids of crop pests. The ability of wild pollinators to provide pollination services is tightly linked to the presence and configuration of habitat on farms. Pollinators need sources of pollen and nectar to sustain them beyond the crop bloom period, as the flight and nesting periods of many species extends significantly beyond the brief bloom of a particular crop, and they need nesting or overwintering habitat that isn't frequently disturbed.

Maintain existing pollinator habitat. Existing on-farm natural or semi-natural areas such as rangelands, fencerows, pivot corners, windbreaks, roadsides, or riparian buffers that contain a diversity of plants can all be habitat for pollinators, making it valuable to retain these features in farm landscapes and prevent further conversion of areas of habitat to cropland.

Install permanent habitat plantings. Existing habitat that supports pollinators is not always present within farms, and growers can add habitat by installing native plant field borders, buffer strips, hedgerows, or meadows. If the farm is located within an intensively managed landscape where plant and habitat diversity is low, these types of permanent habitat plantings become more important. Floral-rich habitat enhancements on the farm can restore pollinators and beneficial insects and encourage their activity within crops or orchards.

Leave some areas untilled. Tillage can disrupt ground-nesting bees and other pollinators that overwinter in the soil. In addition to natural areas or habitat plantings, leave alleyways between crops, service areas, and land around farm buildings untilled when possible so these sites can provide nesting areas for ground-nesting bees.

Alter Practices Within Cropped Areas

Practices within cropped areas can be adjusted to accommodate pollinator life cycles. Short-term habitat plantings, which may not serve as nesting or overwintering habitat due to their temporary nature, can provide dense patches of floral resources.

Include flowering cover crops within fields or in orchard understories. Cover crops can be planted within fields or in the orchard understory to provide a burst of flowers and help to build soil health. When allowed to bloom, cover crops supply pollinators with pollen and nectar. Growing a mix of cover crop species will provide a diverse bloom.

Include insectary plantings within fields. Insectary plantings, temporary seasonal strips or patches of flowering annuals, can support pollinators and beneficial insects within fields or orchards by providing pollen and nectar. If operations and crop rotation plans allow insectary strips to be retained from year to year, install perennial wildflowers for long-lasting benefits.

Reduce tillage and plastic weed barriers. Limit weed barrier fabric where possible because ground-nesting bees and other pollinators that live in the upper soil layers rely on access to the soil. Limiting deep soil tillage wherever possible reduces ground-nesting bee mortality.

Reduce the Risk of Pesticides to Pollinators

There are a number of strategies growers can take to reduce the risk of pesticides to pollinators. Please also see Section 3.2.5 Integrated Pest Management and Pesticide Risk Reduction Recommendations and Section 3.2.6 Integrated Weed Management and Herbicide Recommendations for additional details.

Use integrated pest and pollinator management (IPPM). Integrated pest management (IPM) is a framework that, when there is a demonstrated need for management, utilizes least-hazardous pest management options and takes special precautions to reduce the hazards of pest management activities to people, nontarget organisms, and the environment. An IPM approach to pest control includes preventing pest outbreaks when possible by reducing conditions that favor pest populations, monitoring pest populations to compare levels to established damage or economic thresholds to determine when an established threshold is reached and pest control should occur, and controlling pests with the most targeted pest-control option. The IPM framework can be used to address insect, fungal disease, weed, or other pests and can be adapted to a variety of agricultural production goals, including conventional, organic, or regenerative farming.

Over time, IPM has evolved to meet new production demands. As understanding of the impacts on pesticides on bees and other pollinators grows, IPM is evolving into integrated pest and pollinator management (IPPM), with pollinator health as a central component in some crop systems (Lundin et al. 2021). IPPM can help to reduce the frequency of pesticide applications as well as costs associated with pesticide applications, and can incorporate pollinator and beneficial insect protection strategies to prevent or reduce risks to those important insects (Biddinger and Rajotte 2015). IPPM plans include the use of pesticide alternatives, including pest prevention methods and cultural and mechanical pest control tools. Rather than applying insecticides on a calendar schedule, growers scout fields or orchards for pest problems and track degree-days to know when insecticide applications, if needed, will be most effective at the smallest dose.

Choose less-toxic pesticides whenever possible. Use active ingredients that have the least impact on bees and other pollinators whenever possible. Broad-spectrum insecticides should only be used when field scouting indicates a significant pest problem, and should not be used prophylactically (e.g., seed treatments without demonstrated pest pressure) or on a calendar-based spray schedule. Consider the residual toxicity of a product as well, selecting pesticides that dissipate quickly over those that linger. Use the online Bee Precaution pesticide ratings tool (see listing in resources section below) for information about the toxicity and residual times of various active ingredients.

Avoid hazardous formulations. Use formulations that are less hazardous for bees and pollinators. In general, an oil-based or emulsifiable concentrate formulation of an active ingredient will be more toxic than a water-based suspension concentrate formulation. Similarly, surfactants and penetrants can also increase mortality by increasing the rate at which the active ingredient can infiltrate an insect's cuticle. Some surfactants, whether tank-mixed additives or pre-mix formulations, can also be toxic by themselves. In tree fruit, the use of a higher water volume for application can improve spray coverage and replace the addition of a surfactant in many cases.

Time applications to minimize impacts. Do not apply insecticides that are toxic to bees to a crop in bloom or adjacent to blooming plants. Spraying insecticides at night when pollinators are not active can reduce exposure, with some caveats. Native bees that forage in the early morning (e.g., squash bees) or later in the evening may be exposed to residues outside of the time frame in which honey bees are typically most active. If applying systemic insecticides or fungicides, spraying at night will not reduce exposure to bees and beneficial insects that consume floral resources. Systemic pesticide residues can move into pollen and nectar, and some, such as the four most toxic neonicotinoids (imidacloprid, thiamethoxam, dinotefuran, clothianidin) can be toxic to bees for an extended period of time following application. Cyano-substituted neonicotinoids like acetamiprid are less toxic to bees and have shorter residual periods within plants.

Temperature and dew have a significant effect on the duration of toxicity of most insecticides. In general, cooler temperatures result in much longer periods of toxicity, and dewy nights cause the insecticide to remain wet on the foliage and be more toxic to bees the following morning. It is usually better to apply insecticides when the weather is warmer and at least an hour after sunset because bees are active until dark on hot days.

Reduce drift onto nontarget areas and flowering plants. It is important to reduce drift from the target crop plants to other areas where bees and pollinators are foraging or nesting, breeding, and sheltering. Reduce pesticide drift by spraying under optimal weather conditions and utilizing spray technology that minimizes drift. Apply when wind speeds are 2–10 mph (3–16 kph). Under windier conditions, pesticide droplets can be transported by wind currents onto nearby habitat. Do not apply during a temperature inversion, an indication of which can be the presence of ground fog or wind speeds under 2 mph (3 kph). During temperature inversions, pesticides can linger in the air and will float long distances.

Apply pesticides as close to the crop plants or to the ground as possible. Calibrate spray nozzles regularly to make sure the proper amount of pesticide is being applied. Specialized equipment may also help to reduce pesticide drift. Specially designed nozzles to deliver spray less prone to drift, sensor-based precision sprayers, hooded sprayers that contain the application, or use of GPS to prevent overlapping applications can all help reduce drift as well as the total amount of pesticide applied.

To minimize drift from the target area, leave a 30 ft. (9.1 m) wide pesticide-free buffer around the edge of the target spray area, or at least as much of a buffer as possible. Windbreaks can help contain drift from within or outside the farm. Tree and shrub layers can reduce wind speed and can catch drift droplets. Multiple rows of small-needled evergreens such as spruce, fir, and arborvitae are effective at capturing spray drift. These plants are best for windbreaks designed to limit pesticide drift because they will not attract pollinators and beneficial insects.

Wild bees and other pollinators are susceptible to pesticides used on crops outside of the bloom period, and from drift into the adjacent nesting and foraging habitat. Habitat around a crop or orchard, such as fencerows, hedgerows, or woodlots, can serve as important nesting and foraging habitat. Do not spray this habitat and protect these areas from pesticide drift. Blooming plants in the understory of an orchard can attract foraging bees and pollinators; mow the understory to remove flowering weeds before applying pesticides to reduce bee exposure risk.

To reduce drift from neighboring lands, producers can voluntarily enroll in DriftWatch, a program supported by Colorado's Department of Agriculture, to designate lands where applicators should take appropriate precautions.

Additional Resources

USDA Natural Resources Conservation Service: Technical and Financial Assistance
USDA Service Center Locator
offices.sc.egov.usda.gov/locator/app

Pollinator Conservation Farm Bill Programs (2018-2023), 4th Edition
USDA Natural Resources Conservation Service
directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=49661.wba

Farming for Bees: Guidelines for Providing Native Bee Habitat on Farms
Xerces Society for Invertebrate Conservation
xerces.org/publications/guidelines/farming-for-bees

Cover Cropping for Pollinators and Beneficial Insects
Sustainable Agriculture Research and Education
www.sare.org/wp-content/uploads/Cover-Cropping-for-Pollinators-and-Beneficial-Insects.pdf

UC IPM Bee Precaution Pesticide Ratings tool
University of California, Davis
ipm.ucanr.edu/bee-precaution-pesticide-ratings/

Guidance to Protect Habitat from Pesticide Contamination
Xerces Society for Invertebrate Conservation
xerces.org/publications/fact-sheets/guidance-to-protect-habitat-from-pesticide-contamination

DriftWatch
ag.colorado.gov/driftwatch-pesticide-sensitive-viewer

3.2.2. Mowing & Haying

Mowing

Mowing is a vegetation management tool used to maintain landscaped areas, fields, and roadside vegetation, to reduce fuel loads and prevent risk of fire, and to control invasive weeds or encroaching woody plants. Mowing is also frequently used as a public safety tool, increasing operative (i.e., driving, walking, etc.) and threat (e.g., rattlesnake) visibility along roadsides, campgrounds, and trails. In addition to landscape maintenance, mowing can also be used as a disturbance in place of fire or grazing in grasslands, prairies, and savannas because it is easier to implement (Davison and Kindscher 1999). Mowing can help to increase or maintain plant diversity in grasslands and similar natural areas, for example, and can be timed to suppress weeds or dominant species (Collins et al. 1998). Early spring mowing, for example, can remove cool-season weedy annual grasses, while repeated mowing in the early months after habitat has been seeded can help remove annual weeds and allow sunlight to reach new native seedlings (Williams et al. 2007). Mowing in the summer or fall can also help to spread wildflower seeds and reduce thatch buildup in the dormant season.

Ultimately, mowing plans will depend upon vegetation management goals, but it is also important to consider the needs of pollinators. Mowing can kill pollinators nesting or feeding in the habitat; for example, caterpillars of butterflies and moths are vulnerable to mowing, as are bumble bee nests that occur in grass thatch (Thomas 1984; Wynhoff 1998; Di Giulio et al. 2001; Humbert et al. 2010; Hatfield et al. 2012; Steidle et al. 2022). Mowing can also affect adult pollinators indirectly by temporarily removing host plants for butterflies and moths and the plants that provide pollen and nectar (Morris 2000; Johst et al. 2006; Noordijk et al. 2009). Vegetation structure as well as other habitat features that provide overwintering sites or temporary shelter are also altered by mowing. In addition, higher mowing frequencies reduce native plant growth, plant diversity, the ability of forbs to compete with grasses, and the amount of nectar and pollen present over time (Parr and Way 1988; Williams et al. 2007). Also, if implemented repeatedly at the same time each year, mowing can reduce the abundance of certain flowering plants over time.

Significant decreases in adult butterflies occur immediately following mowing. However, when not all areas are mown in the same year, populations rebound more quickly (Weber et al. 2008). Mowing of pollinator habitat can have temporary detrimental effects on pollinators in general, but can have more significant impacts on imperiled pollinators that have small populations and particular habitat needs. If an imperiled pollinator species occurs in the area, the impacts of mowing can be reduced by mowing outside of their activity periods, by leaving unmown areas of their habitat nearby so that their populations can rebound, and not mowing the same location at the same time every year.

Figure 3.6. Roadside mowing along a Colorado highway. (Photo: Colorado Department of Transportation.)

Recommendations for Mowing That Apply to All Landscapes

Reduce the Frequency of Mowing

Reducing the frequency of mowing can improve existing habitat for pollinators by allowing flowering plants to bloom. Mowing is an important tool for maintaining predominately herbaceous plant communities, but frequent and routine mowing is often unnecessary and can be costly. Frequent mowing can also reduce wildflower bloom and stunt plant growth, reducing wildflowers over time and consequently, the diversity and abundance of pollinators.

Reduce routine mowing of areas that serve as pollinator habitat. Assess areas of potential pollinator habitat where mowing is currently conducted (prairie, meadows, roadsides) to reduce routine mowing. Where possible, reduce the frequency of mowing to once or no more than twice a growing season. Mow only when there is a well-defined objective, such as reducing brush or weeds, maintaining lines of sight, wildfire mitigation, or mowing to influence plant diversity.

Use rotational mowing to mow only a portion of the habitat. Aim to mow no more than one-third to one-half of an area per year. Rotational mowing leaves behind intact vegetation that can support pollinators. In addition, this heterogeneous mowing strategy can help prevent gaps in blooming, promote beneficial seed dispersal, and enhance the diversity of flowering species across the site.

Maintain a regularly mown border adjacent to the habitat. A regularly mown edge creates a neat border (referred to as a "cue to care"), which can increase the acceptance by the general public of a more "messy" appearance of the habitat (e.g., Nemec et al. 2021).

Consider the Timing of Mowing

When mowing is conducted during the growing season it can interrupt the life cycle of some pollinators (e.g., butterflies) and reduce wildflower bloom. Mowing can be timed to reduce impacts on pollinators and to promote wildflower growth.

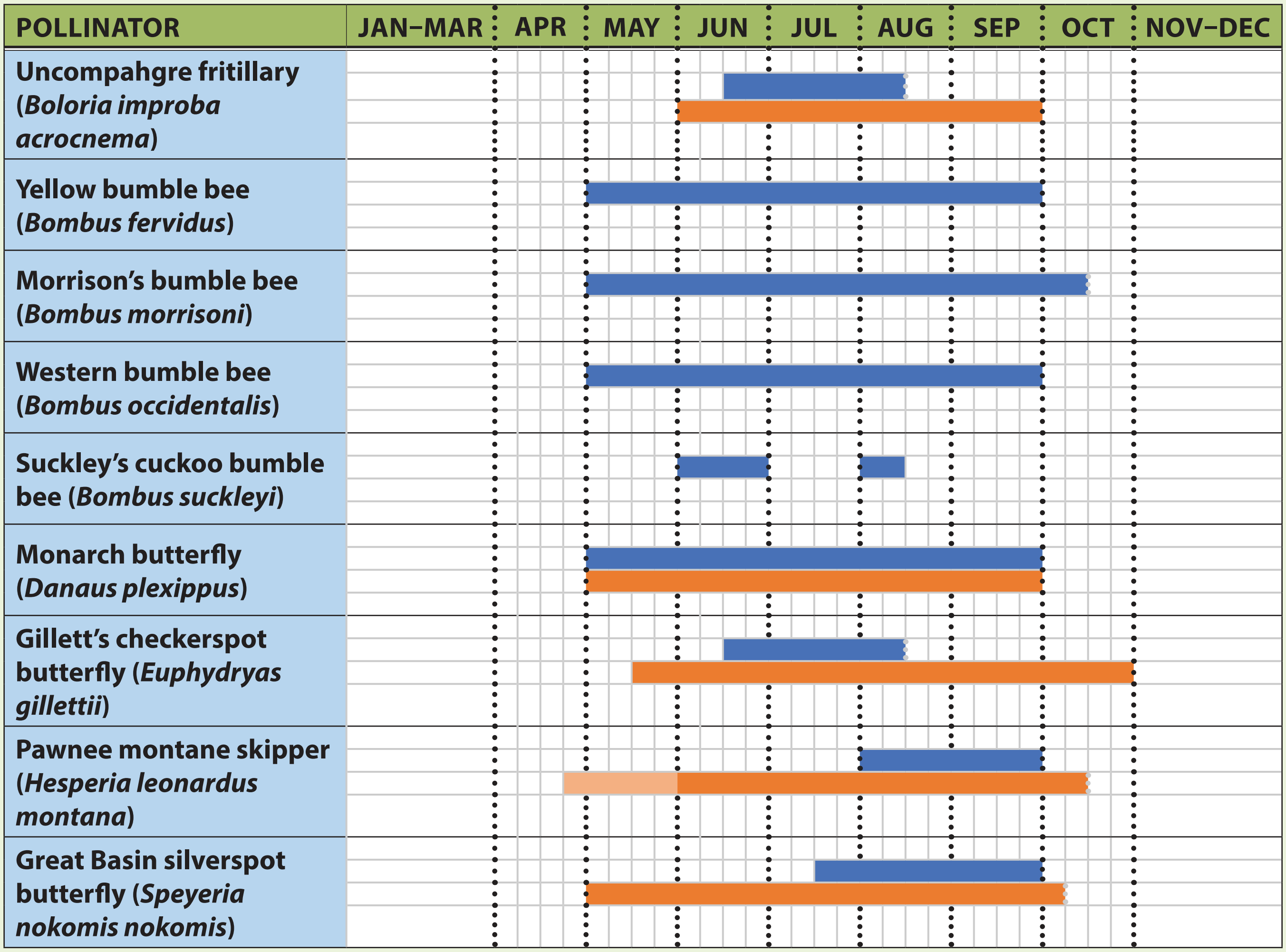
Delay mowing until after the first frost. If operational constraints allow it, delay mowing until after the first frost. This allows butterflies and other pollinators with larval stages that reside on vegetation to complete their full life cycles, and enables flowering plants to bloom and provide pollen and nectar to pollinators uninterrupted throughout the growing season. A mowing event in autumn can also help spread wildflower seeds or target woody species that can invade herbaceous habitat.

Balance vegetation management goals with pollinator needs. If mowing must take place during the growing season, consider selecting a time to mow that balances vegetation management needs (e.g., noxious weed control) with the resource needs of pollinators (e.g., flowers and host plants). For example, mow at a time that will promote the growth of wildflowers; though the temporary removal of flowers will be harmful in the short term, mowing will benefit pollinators in the long term. Local site conditions and vegetation management goals will also influence the timing of mowing. If needed, consult with regional native plant experts on the best time to mow to promote wildflowers.

The timing of mowing can be targeted to reduce the abundance of a dominant plant species or thatch and other plant litter and to aid wildflower seed dispersal. To reduce the cover of an unwanted herbaceous species, mow when the plant is most vulnerable (i.e., during its growing season but prior to bloom or before seeds set). This action can help limit the new growth of unwanted or dominant species the following year and create space for other species to grow. It is also worth considering varying the season when mowing takes place to increase plant diversity. Mowing consistently at the same time every year will favor some plants over others. Plant diversity can be maintained by occasionally varying the timing of mowing, which will favor different plants and prevent certain plants from dominating the planting.

Time mowing to avoid vulnerable life stages of imperiled pollinator species. If an imperiled pollinator species is present, avoid mowing during their breeding season and adult flight times. (Table 3.1 [next page] summary of natural history info of imperiled species in Colorado). For example, avoid mowing during May–September if an imperiled bumble bee species that nests in grass thatch is present, such as the American bumble bee (*Bombus pensylvanicus*). Similarly, if an imperiled butterfly is present, avoid mowing its host plant during the period its caterpillars are active. An example is the Pawnee montane skipper (*Hesperia leonardus montana*), whose caterpillars may be feeding on blue grama (*Bouteloua gracilis*) between June and September.

Table 3.1. Periods of Imperiled Pollinator Activity to Avoid When Conducting Maintenance Activities in the Rocky Mountains*



* This table was adapted from data contained within volumes 12-15 of Pollinator Habitat Conservation along Roadways, published by National Academy of Sciences

† The list of imperiled pollinators is an example with only some regional imperiled species illustrated. Note: Adult flight times are in blue, and larval active times (for species that have larvae active outside of a nest) are in orange. Lighter shades indicate uncertain but likely active times; data are limited on the phenology of larval activity. If local experts are available, they should be consulted to make the best-informed decisions on the timing of maintenance activities.

Mow weeds before they flower. Conduct mowing before weeds have seed heads to reduce the spread of noxious weeds at the site. This limits the number of weed seeds that attach to mowing equipment and potentially get moved to a different site.

Adopt Additional Mowing Techniques That Reduce Impacts on Pollinators

Mowing destroys structural diversity and potential pollinator nesting habitat, but there are some mowing techniques that can reduce harm to pollinators. Many of these techniques also protect wildlife such as ground-nesting birds.

Raise the mowing height. Set mower blades higher to allow faster recovery of vegetation and reduce stress on plants during dry periods or drought. It also leaves a greater depth of vegetation for pollinators to use and shelter in during mowing operations.

Avoid mowing early in the morning, at dusk, or at night when pollinators are less active and adults are less likely to be able to escape the mower's blades.

Help adult pollinators to escape. Use a flushing bar, which may encourage adult pollinators to fly out of the vegetation before the mower's blades reach them, and consider reducing the speed of the mower to allow adult pollinators time to escape.

If using mowing to control invasive or noxious weeds, target mowing. For example:

- *Use spot mowing for weeds*. If weed management is the management objective, mow only the patches of weeds rather than the whole area.
- *Know the impacts of mowing on the target weed or undesirable plant*. Become familiar with the life history traits of target weeds. Some species are stimulated by mowing, so alternative control methods are preferable when those species are present.
- *Clean mowing equipment between sites*. After equipment is driven through areas of dense weed infestations, avoid spreading weed seeds between sites by spraying the vehicle's tires and undercarriage with an air compressor to remove weed seeds and prevent their unintentional spread.

In addition to the mowing recommendations above, there are several considerations that are unique to particular landscapes.

Recommendations Unique to Mowing in Built Environments

Roadsides

Restrict mowing to the clear/safety zone as much as possible. Frequent and routine mowing within the clear/safety zone allows vehicles to safely pull off the roadway and creates an environment that is not typically used by pollinators as habitat because it does not often support flowering plants or places to shelter. Mow as frequently as necessary in high-crash zones and within lines of sight, so roadside vegetation doesn't impede driver visibility. Mow in the operational, buffer, or natural zone only when there is a well-defined objective, such as reducing brush, controlling weeds, or enhancing plant diversity. The Colorado Department of Transportation Maintenance Manual provides more detailed information on mowing in each roadside zone.

Limit mowing beyond the clear/safety zone. Reducing mowing of the entire right-of-way (fence to fence) will benefit pollinators by allowing wildflowers to bloom, thereby supplying nectar and pollen as food. Although many perennial wildflowers will recover from a mowing event, some may not be able to flower and reseed in the same year of a mowing event and thus will not increase their populations. If mowed before they bloom, many annuals will not be able to flower and produce seeds and may subsequently disappear from a site.
In some parts of Colorado, mowing might be needed every other year or every 2 to 3 years, depending on the intervals of mowing needed to control woody plant encroachment or reinvigorate populations of wildflowers. Consider conducting mowing trials to determine the most optimal mowing intervals needed to manage encroaching woody plants.

If an imperiled pollinator species has a known mortality hot spot due to vehicle collisions, consider possible mitigation strategies to limit mortality. Mortality hot spots for butterflies and other pollinators are not well understood, but may occur if landscapes funnel pollinators through high-traffic zones or due to the flight patterns of a particular species. For example, pollinators that are poor fliers or normally fly low to the ground may be more vulnerable to vehicle collisions than pollinators that are strong fliers or normally fly high above the ground (Hopwood et al. 2015; Phillips et al. 2021). Mitigation efforts could include reducing traffic speeds temporarily for a mile or two near the hot spot, using fencing or netting to cause pollinators to fly higher when crossing the road, closing the outer lanes of traffic temporarily during the peak breeding season, or widening the mown strip within the recovery area to create more distance between the road and the habitat used by a pollinator (Zielin 2010; Kantola et al. 2019).

Additional Resources

Pollinator Habitat Conservation Along Roadways
National Academies of Sciences, Engineering, and Medicine (NASEM); Transportation Research Board (TRB); National Cooperative Highway Research Program (NCHRP)

- Volume 12: Northern Plains Region
  nap.nationalacademies.org/catalog/27088/pollinator-habitat-conservation-along-roadways-volume-12-northern-plains
- Volume 13: Rocky Mountains Region
  [...]/27121/pollinator-habitat-conservation-along-roadways-volume-13-rocky-mountains
- Volume 15: Southern Plains Region
  [...]/27119/pollinator-habitat-conservation-along-roadways-volume-15-southern-plains
- Volume 16: Southwest Region
  [...]/27118/pollinator-habitat-conservation-along-roadways-volume-16-southwest

Mowing and Management: Best Practices for Monarchs
Monarch Joint Venture
mjv.nyc3.cdn.digitaloceanspaces.com/documents/BMPs/MowingForMonarchsUpdated.pdf

Landscaped Areas

Assess existing greenspaces for their potential value to pollinators. Many green spaces have small areas that can be given over to pollinators. Some have native plant seed banks and often just by reducing maintenance pressure, native vegetation will be allowed to bloom and can return over time. Awkward-to-mow corners, fencerows, the bases of hedgerows, trails and roadsides, the margins of sports fields, and banks of creeks and drainage ditches offer pollinator nesting and foraging habitat if mowing in these areas is reduced. Additionally, these areas often connect other patches of habitat, providing a corridor along which pollinators (and other beneficial insects and wildlife) can move through the landscape.

Establish perennial ground covers. Reduce the amount of lawn or turf that requires mowing by establishing drought-tolerant perennial blooming ground covers, including native species such as winecup (*Callirhoe involucrata*), spreading fleabane (*Erigeron divergens*) or introduced cover plants like thyme (*Thymus* spp.) and sedum (*Sedum* spp.), and low-growing warm-season grasses such as buffalo grass (*Bouteloua dactyloides*) and blue grama grass (*Bouteloua gracilis*).

Allow flowers in lawns to bloom. In larger areas of turf or grass where clover, dandelions, violets, or other low-growing blooming plants may exist within the lawn, consider less intensive mowing or mowing sections on a rotation instead of all at once to allow insects to move between different areas and flowers to remain intact.

Recommendations Unique to Mowing on Natural Lands (e.g., Wildlife & Habitat Conservation Areas)

Leave refugia from mowing. Use rotational mowing or mowing in a mosaic of patches over several years, rather than mowing an entire site at once, to allow sufficient space and time for pollinator populations to recover from the impacts of mowing. If using mowing to control weeds, target mowing by limiting repeated mowing to dense weed patches.

Employ another vegetation management strategy. Implement prescribed grazing or another vegetation management strategy, where feasible, that might support biodiversity in ways that mowing cannot (e.g., prescribed grazing can be conducted to support soil health). Mowing often occurs on natural lands to reduce fuel loads but grazing in the fall or early winter can also reduce thatch.

Haying

Haying, the cutting, drying, and baling of grassland vegetation, is used by producers in rangelands and other grasslands to create livestock feed to be used during the winter or in times of drought. Like mowing, haying can also be an important management tool for conservation. Haylands can be important for biodiversity (Jog et al. 2006; Foster et al. 2009) and haying can be used to enhance plant diversity and suppress the growth or encroachment of woody vegetation in grasslands (KBS 2007). Conservation haying also reduces light competition from tall grasses, allowing spring-blooming flowers and short-statured plants to thrive (Foster et al. 2009). For example, haying when dominant grasses are in the reproductive stage (seed heads are forming inside of the grass sheath) can increase light and moisture availability to wildflowers (McCain et al. 2010). Haying differs from mowing in that the resulting litter is removed from the site. As such, haying can be even more effective than mowing at promoting wildflowers because excess nutrients are removed, promoting soils that favor desired plant communities in place of weeds. Moreover, haying can provide direct economic value from pollinator habitat, since the cut and dried herbage can be sold or used as livestock forage, bedding, or mulch.

Annual haying when the protein content of native grasses is at peak can reduce dominant warm-season grasses, but will also negatively impact wildflowers that are actively growing during that time period and have not yet bloomed. Haying at the same time each year promotes plant species that bloom before the haying event, begin growth after the haying event, or can quickly recover and bloom. Thus, varying the timing of haying may increase overall plant diversity in haylands. The productivity of grasslands can be influenced by the timing of haying and the frequency. Two cuttings per growing season can reduce biomass the following year, and delaying a single cutting until late in the summer also weakens plants going into winter and reduces yields the next growing season (KBS 2007).

While haying can benefit plant communities, it can also pose risks to pollinators and other wildlife by abruptly removing flowers and host plant vegetation, destroying immobile eggs and larvae (Humbert et al.

Figure 3.7. Drying and baled hay in Custer County, Colorado. (Photo: K. Wommack.)

2010), and removing nesting sites, especially for stem-nesting bees and above-ground colonies of bumble bees (Black et al. 2011). Consideration of scale, technique, and timing can help protect pollinators from these impacts. Haying may be less destructive to butterfly species that rely on grasslands than burning (Swengel 1996), and with unhayed refugia, impacts on pollinators can be reduced (Feber et al. 1996).

Recommendations for Haying That Apply to All Landscapes

Haying is an important tool for maintaining grassland plant communities and is a key component of livestock management for some producers. As with mowing, the timing and scale of haying can be influential in reducing negative impacts on pollinators.

Limit the frequency of haying. Cut hay only once per year, to maintain grassland health and productivity as well as pollinator populations. A second cutting will reduce yields the following year and will not allow most wildflowers time to recover and bloom.

Consider rotational haying. Where possible, limit haying to one third or less of a particular pasture in a given year, leaving unharvested areas to support pollinators. Rotate the cut area annually, so that each parcel is cut every three years. Alternatively, hay in strips or patches. If the whole site must be cut each year, offset the timing of cuttings, haying one half early in the season (e.g., late-June or early July) and one half later in the season (e.g., late-August or early September).

Consider the timing of haying. Cutting after the peak bloom of wildflowers minimizes sudden reductions in food sources for pollinators during the growing season. However, if hay is harvested for livestock forage, the nutritional content of hay is past its peak in the fall, and harvesting later in the growing season can reduce yields the following year. If haying for conservation, consider varying the season of haying from year to year (to avoid harming the same plant and pollinator species across years).

Help pollinators escape. Hay at reduced speeds (less than 8 mph [13 kph]), so adult pollinators can escape the blades of the mower or windrower.

Time haying to avoid vulnerable life stages of imperiled pollinator species. If an imperiled pollinator species is present, avoid haying during their breeding season/adult flight times or avoid haying in select areas that can act as refugia (see Appendix IV for profiles of imperiled pollinators in Colorado). Avoid mowing early in the morning, at dusk, or at night when pollinators are less active and adults are less likely to be able to escape the mower's blades.

State Pollinator Conservation Mowing Practices

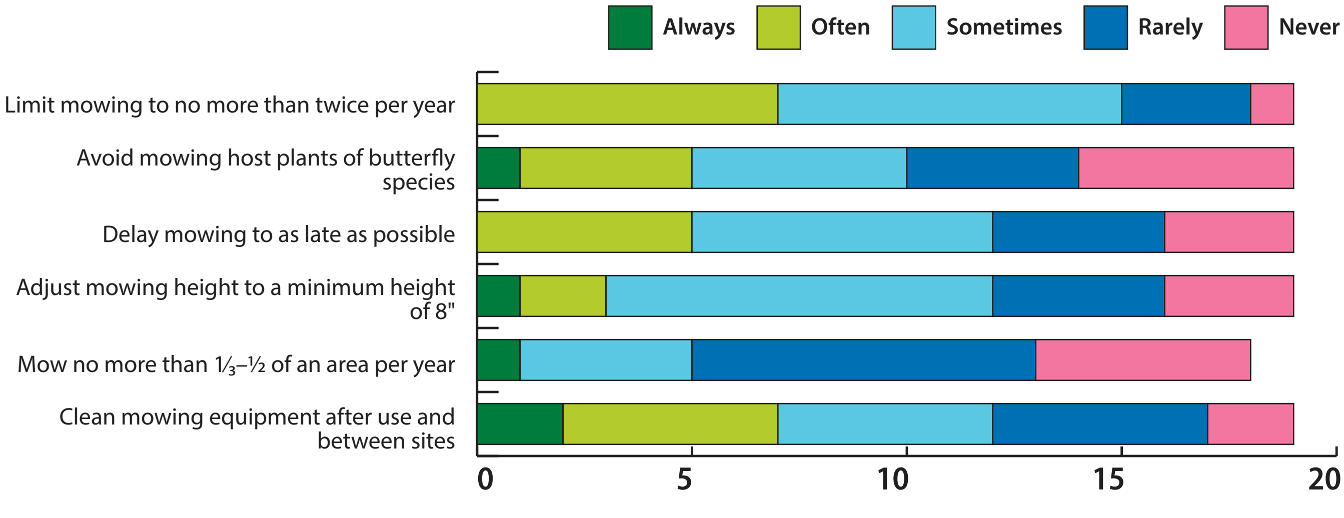
A survey of state staff assessed the frequency of use of different pollinator-related land management practices. Over 65% of respondents reported implementing mowing, and responses indicated that mowing is commonly used (sometimes, 21%; often, 37%; always, 16%). Mowing practices that support pollinators are most relevant for two agencies, Colorado Department of Transportation (CDOT) and Colorado Parks and Wildlife (CPW). Haying, which is much less commonly used by state agencies (never, 37%; rarely, 11%; sometimes, 37%), is most relevant to CPW and the Colorado State Land Board (SLB).

The survey responses identified the pollinator-supporting mowing practices that are most or least commonly used by state agency:

- Most implemented were cleaning mowing equipment and mowing no more than twice per year.
- Moderately implemented were mowing at a high height and mowing late in the growing season.
- Least implemented were avoiding mowing of host plants and rotational mowing.

Figure 3.8 (below) shows the frequency at which state agencies currently implement different pollinator conservation mowing practices. The survey also inquired about the feasibility of implementing the specific mowing practice of limiting mowing to one or two cuts per growing season. Responses conveyed that this practice tended to be more feasible (medium, 28%; high, 38%) than less (low, 13%), perhaps indicating a good opportunity for increasing the use of a pollinator-friendly practice. One approach to using these survey results

Figure 3.8: How frequently does your agency currently implement the following mowing practices?



is to consider ways of increasing the use of any of these practices, and ideally target the practices that are less frequently applied (rarely or sometimes used). This could include looking for ways to increase the practice of raising mower heights and rotating areas that are mowed.

Challenges & Barriers to Implementing Pollinator Conservation Mowing Practices

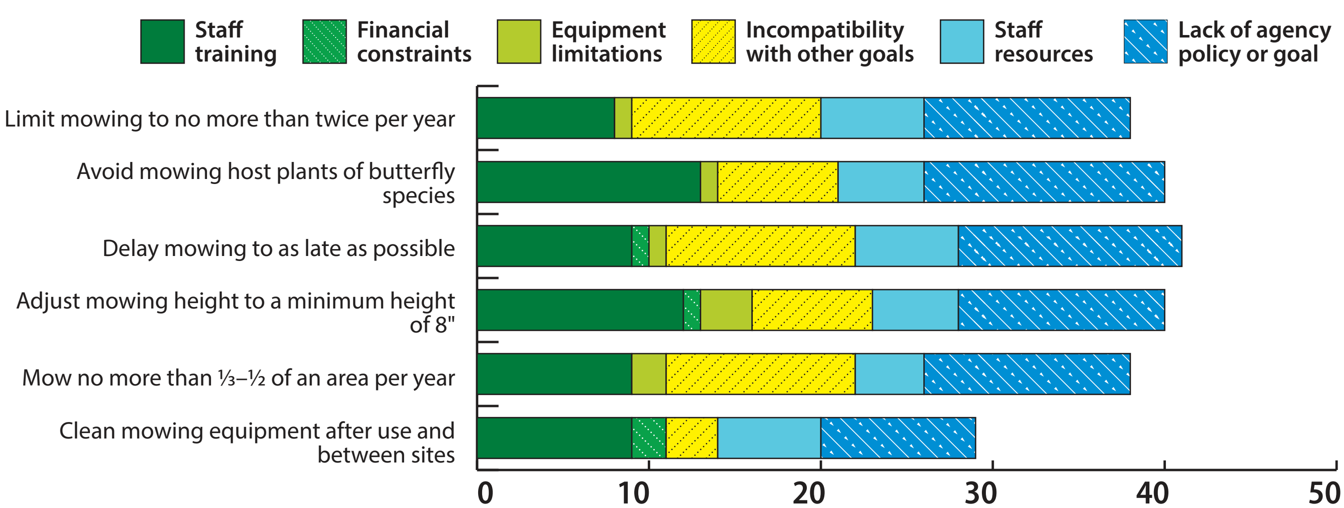
The staff survey and interviews also provided insight into the hurdles or barriers that limit or inhibit more frequent or broader use of conservation mowing practices. Survey results showing the common barriers to implementing pollinator mowing practices are available in Figure 3.9 (below). These results highlighted that four barriers play an important role in commonly affecting the implementation of pollinator-oriented practices:

- Lack of agency policy or goal,
- Lack of staff training,
- Incompatibility with other goals, and
- Lack of staffing resources.

That both a lack of agency policy or goal and a lack of staff training show up as important hurdles is not surprising, because generally when an agency has policy or procedural directives guiding operational practices, there tends to be a corresponding higher priority for establishing and providing training that supports and activates the policy or procedures. Staff interviews provided further insight by pointing out that pollinators are not typically considered when making adjustments to mowing or haying practices, even though some adjustments are made for other wildlife such as nesting birds. Interviews also highlighted that mowing practices are often influenced by aesthetic or safety reasons rather than conservation purposes, again highlighting the value of establishing or integrating pollinator conservation objectives into mowing policies and procedures.

The lack of staffing resources was also raised as a barrier to implementing conservation practices that include having the staff available to do the work and also to implement the specific practices during the desired timeframes, with the necessary training, and flexibility to monitor and adapt practices for site-specific circumstances. Staff

Figure 3.9: What are the barriers for your agency to implement these mowing practices?



> "Our internal policies steer the agency and our projects in directions that protect native habitats. These policies help to dictate the way we do business while achieving management and project goals."
>
> - Colorado Native Pollinating Insects Health Study Agency Interview Participant

indicated a corresponding staffing capacity issue, a high turnover rate for positions responsible for mowing that made it challenging to have consistency in staff who were trained and knowledgeable about how and when to implement practices that require greater training and experience. Thus, exploring opportunities for increasing available funds for staffing and staff time allotted to training and implementing pollinator-supportive mowing practices is an important consideration to support staff efforts to implement these mowing practices. CDOT reported that guidelines for roadside zones 2 and 3—those beyond the clear zone mowed as needed for safety reasons—are that they should be rarely mowed (every 3–5 years), but in actuality are mowed more frequently due to aesthetics. Internal training and support could help staff understand the value of reduced mowing frequency.

Another challenge identified by staff is that for some state land, management is implemented by the person who leases the property. This is a common situation for SLB. In many of these lease arrangements, staff can help educate about practices and provide recommendations, but often don't have the authority or ability to prescribe management practices. Integrating pollinator practices into educational information shared with lessees and potentially giving preferences to leases that integrate conservation practices or developing policy to prioritize pollinator conservation for areas with the highest pollinator conservation value could be approaches to reduce this barrier. For lands where imperiled pollinators occur or those that contain particular high-quality pollinator habitats, building specific pollinator conservation recommendations into the lease may be a way to ensure pollinator health is protected in these important habitats.

3.2.3. Forests, Shrublands, and Trees

Forests, Shrublands, and Trees as Pollinator Habitat

The shrublands, woodlands, and forests of Colorado range from drier sagebrush and pinyon–juniper ecosystems at lower elevations to ponderosa and lodgepole forests in the lower mountains and subalpine fir and spruce forests in the colder, moist higher elevations. Colorado's riparian corridors and waterways also support a rich diversity of trees and shrubs. Trees and shrubs can also be part of the matrix of vegetation along roadways, in urban spaces, and on working lands throughout the state. The management of woody vegetation can take shape in many ways and in varied landscapes, from large-scale, landscape-wide habitat management to small-scale maintenance and caretaking of trees and bushes. At all scales, woody vegetation and the management of these resources is relevant to, and is an important component of, pollinator habitat.

Forests & Shrublands

Prioritizing silvicultural practices that help create and sustain diverse and climate-resilient forest and shrubland ecosystems is important for sustaining the health of these environments with all sorts of wildlife including pollinators. Healthy practices include ensuring forests do not become overly uniform in age structure, dense, and overcrowded where they have significantly less diverse vegetation and are less resilient

Figure 3.10. Small mountain meadow surrounded by ponderosa pine (*Pinus ponderosa*) and shrubs in Larimer County, Colorado. (Photo: Steve Armstead.)

to large stand-replacing disturbances including big or high-intensity wildfires. Other valuable practices include those that restore complexity both within a stand and across the landscape and help to promote a diversity of vegetation, the regeneration and restoration of native flora, and vegetative structural diversity. For pollinator conservation, most current forest and shrubland management practices aimed at sustaining healthy conditions and resilient to pests, disease, and climate change are inherently synergistic with conditions beneficial to pollinators (Glenny et al. 2022).

Many of Colorado's forests have evolved with a history of natural disturbance including wildfire, floods, avalanches, wind events, insect infestations, and disease. Disturbances can serve to ensure a diversity of forest types, ages, and densities occur throughout a landscape, so that a matrix of habitat for wildlife and pollinators exists. A history of fire suppression across the western states, and here in Colorado, has resulted in some forested areas that are even aged and crowded with closed canopies that exclude understory vegetation, have reduced early seral habitats, reduced connectivity of open habitats, and limited edge habitats that likely provide important areas for foraging, nesting, and overwintering pollinators (Schultz and Crone 2008; Cannon et al. 2018). Forest management—and the removal of trees when it occurs—is primarily for harvesting forest products, to create wildlife habitat, to address safety concerns, and mitigate the risk of wildfires. The removal of trees creates openings in canopies that increase nutrient flux and light availability. When done responsibly as part of ecological forestry, this increase in light supports shrub and herbaceous plant growth that provides pollen, nectar, and host plants for moths and butterflies and improves habitat for all sorts of pollinators (Waltz and Covington 2004; Korpela et al. 2015). When these habitats are diverse with native plant communities that bloom from spring to fall, openings are even better habitat for bees and other pollinators.

Tree and shrub removal may occur with the purpose of helping to prevent meadows from being overrun by woody species and shrublands being overrun by trees. The thinning and removal of Rocky Mountain juniper trees (*Juniperus scopulorum*) in areas of Colorado is important to control juniper expansion and its dominance into shrubland ecosystems. This is particularly important in sage-grouse habitats where juniper tree dominance has the potential to reduce herbaceous and shrub abundance and diversity, decrease wildlife habitat, and increase the potential for erosion and runoff.

While there are several broader forest management practices that help to maintain healthy forests and also serve to improve habitat for pollinators, there is also unfortunately a lack of applied research and knowledge about the risks and benefits of management actions to pollinators relative to the types of tree and scrubland environments common in Colorado. As a result, management recommendations provided in this section of the report are more general in nature. They are important to integrate into resource management programs and practices because they represent some of the best information available. However, there is a clear need for additional studies, researcher and resource manager collaborations, and adaptive management to determine for Colorado's forests and shrublands, which and how different management practices contribute best to sustaining healthy forest and shrubland conditions for pollinators.

Trees & Shrubs as a Pollinator Resource

Efforts to conserve and increase the number native wildflowers tends to be the most common element of pollinator habitat that gets attention, and for good reason. However, trees and shrubs can also be important resources for pollinators, and need to also be considered as they provide important forage and resources for nests and shelters.

Shrubs and trees can provide significant forage resources for pollinators and may have flowers that bloom at times of the year when other floral resources are limited. Shrubs and trees that bloom in early spring can be vital nectar and pollen sources for early emerging pollinators, and very important for bumble bee queens beginning nest and colony establishment (Mola et al. 2021). The larvae of many butterflies and moths feed on tree and shrub foliage while also providing a food source for birds that feed on caterpillars and the winged adults. Research has found that native trees and shrubs support a much higher number of butterfly and moth larvae—both in terms of species diversity and caterpillar abundance—than non-native species (Tallamy & Shropshire 2009). Flowering trees and shrubs can also provide denser forage opportunities for pollinators, meaning that a pollinator doesn't have to travel as far between blooms or spend additional time searching for what it needs. Trees and woody vegetation may even help bees create a cognitive map of foraging areas to aid in navigation (Donkersley 2019).

Pollinators also depend on trees and bushes to provide nesting and sheltering resources. Butterflies and moths use woody vegetation for roosting during their flight periods and shelter during wind and rain events. Snags can provide nesting habitat for some types of bees, including tunnel-nesting species that use old borer beetle tunnels as nesting sites. The protected spaces under a fallen log or behind the peeling bark also provide shelter and overwintering resources for pollinators and other invertebrates. Pollinators may also depend on other organisms that live in woody environments; for example, the larvae of certain syrphid flies and some beetles prey upon microorganisms in dead wood (Dunn et al. 2020). Many bees, such as leafcutter, mason, and small carpenter bees nest in pithy- or hollow-stemmed plants and bushes such as elderberry and sumac. These bees also overwinter in the stems, so it is important to have stem-nesting and sheltering resources available year-round.

Maintaining and providing tree and shrub resources for pollinators in all types of landscapes can play an important role in the life cycle of pollinators and in conserving a rich diversity of pollinators. Whether that landscape is a forest, along a roadway, in a park, a garden, or a farm, there are conservation management practices that when implemented, can improve conditions for pollinators.

Recommendations for Forest & Shrubland Management to Benefit Pollinators

The following section includes pollinator conservation practice recommendations that the state can integrate into forest and shrubland resource management plans and into procedural guidelines for tree thinning and fuel load management operations.

Managing for Healthy Forest & Shrubland Ecosystems to Benefit Pollinators

Manage for Tree and Shrub Diversity According to Each Site's Unique Characteristics. Different tree and shrub species support different pollinators, have different wood textures, are larval host plants for different caterpillars, provide different nutritional value, and cover different bloom periods with pollen and nectar availability. Not all of the same species are appropriate for each site. The goal is to manage for a species diversity, density, and age-class distribution that will provide long-term climate resiliency appropriate for each site. The silvicultural strategies that will be most appropriate in order to get a healthy diversity of tree and shrub species and ages will differ based on a site's history, soil type, sun exposure, topography, and resource management goals. However, as planned management interventions are taken site by site, it will help to restore forest and shrubland health and diversity across the landscape and help maintain better habitat conditions for pollinators.

Use tools and techniques to reduce forest fuel loads that minimize impacts to herbaceous plants, and if feasible, integrate the use of prescribed fire. The thinning and removal of woody vegetation in accordance with forest management objectives aimed at improving forest health, wildlife habitat, and the mitigation of wildfire prone areas can decrease the likelihood of large high-intensity, stand-replacing wildfires and subsequently create more climate-resilient forests. Using techniques and equipment that minimizes the disturbance to herbaceous vegetation will help maintain pollinator foraging resources as well as overwintering habitat for butterflies, moths, flies, and beetles.

Maintain patches of thin and dense forest stands with intermittent forest openings. Manage forests to promote heterogeneous patches of thinner and denser stands to provide a matrix of foraging and nesting resources for pollinators and other wildlife. Selectively thin overcrowded stands to open the canopy, increase solar radiation, and increase herbaceous understory vegetation. Follow up tree thinning and removal efforts and repeat as necessary to maintain wildlife and pollinator openings while also allowing some gaps to fill in as other new gaps are created. Maintaining a diversity of openings and different seral stages of openings can help increase the diversity of tree species available and a broader matrix of condition for pollinators such as when quaking aspen (*Populus tremuloides*) colonize into an opening or thinner patch of forest.

Include pollinator-specific habitat and resource needs in forest and woody vegetation management plans and prescriptions. In forests, woodlands, and shrublands that have resource or forest management plans and for specific stand prescriptions, integrate pollinator conservation objectives and practices whenever feasible.

Feather or soften forest edges. Create a transitional area between trees and adjacent shrub or grass vegetation. This can be done by thinning portions of the tree canopy along the edge next to grassy and brushy areas. Shrubs and small trees that grow on the edges of forests provide food, nesting habitat, and overwintering habitat for pollinators. Flowering shrubs and trees often bloom at a time of year when other floral resources may be scarce. They can be particularly important to early emerging pollinators, like queen bumble bees.

Leave snags or trees with cavities. Where they pose no safety risk, leave snags or trees with cavities to create features for pollinators to nest and overwinter. This resource is particularly important for native solitary bees and tunnel- and cavity-nesting pollinators as well as other invertebrates. Snags can be very important to pollinators like yellow-faced bees (*Hylaeus* spp.). Snags and tree cavities also are important resources for birds and other wildlife.

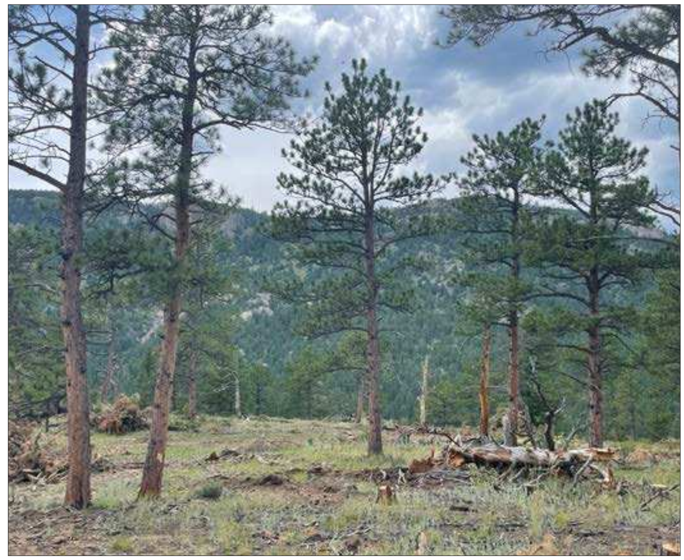


Figure 3.11. Forest mitigation work in Boulder County, Colorado including tree thinning, leaving snags, and retaining woody debris (Photo: Boulder County Parks and Open Space.)

Leave woody debris. Where they pose no safety risk and while ensuring the fuel load is low enough to mitigate the risk of high intensity wildfire, leave downed woody debris, rotting logs, and brush piles. Brush piles provide hibernation sites for pollinators including butterflies, nesting sites for bumble bees, daytime shelter, and food for wood-eating beetles and other organisms that eventually break the piles down to valuable organic matter. Wood-boring beetle larvae often fill dead trees and branches with narrow tunnels where tunnel-nesting bees will subsequently establish nests.

Include native plants beneficial to pollinators in restoration seed mixes. Include locally or regionally appropriate native wildflower and host plant seeds in seed mixes used for overseeding (interseeding) or restoration projects.

Plan vegetation management to avoid vulnerable times for imperiled pollinator species. When planning and scheduling forest management work or woody vegetation removal in locations where imperiled pollinator species are present, avoid peak breeding periods and adult flight times. (See Table 3.1 for more information about periods of imperiled pollinator activity to avoid when conducting maintenance activities). In areas where imperiled bumble bees such as the western bumble bee (Bombus occidentalis) occur, schedule activities during summer or early fall, and avoid the nest initiation phase that occurs in the spring. Also, use care during the winter when queen bumble bees are overwintering in the upper soil layer or under leaf litter or trees and shrubs.

Avoid or Minimize Practices That Introduce or Spread Invasive Plants

Minimize soil disturbance and damage to herbaceous plants. When implementing forest or shrubland management actions such as thinning or fuel reduction efforts, and especially when vehicles and machinery are involved, it is important to minimize soil disturbance as much as is reasonably possible. Reducing soil disturbing activities aids in avoiding the spread of invasive plants and bringing new weed seeds to the surface. Soil disturbances can destroy pollinator overwintering sites or nests, and deeper soil disturbances (e.g., heavy equipment operations in muddy and wet areas) can possibly destroy underground bee nests.

Clean wheeled or tracked equipment between sites. After equipment is driven through areas with weed infestations, avoid spreading weed seeds between sites by spraying the vehicle's tires or tracks and undercarriage with an air compressor to remove weed seeds and prevent their unintentional spread. Reducing the movement of soil among sites not only reduces the movement of weed seeds but also the potential of moving other pest species living in the soil.

Practice Adaptive Management

Forest and woody vegetation management actions must be dynamic and suitable for the site-specific conditions where they are being applied. Therefore, to ensure desired conditions are achieved for sustaining healthy forest and shrubland conditions for pollinators, adaptive management should be integrated into management plans and operations that carry out the plans. Adaptive management encourages that assessments occur of specific site conditions, the effectiveness of management actions are evaluated, and that adaptive changes to management actions are based on observed changes in conditions and new information gained. To safeguard that forest and woody habitats retain key components important to pollinators such as a diverse forest structure, openings, woody debris, snags, and floral and host plant resources, management actions may need to be modified over time and recalibrated to match where conditions are in greatest need for change. Large natural disturbances such as wildfires or forest pests or disease outbreak may change conditions rapidly and thus trigger potentially significant adjustments in actions and the implementation of new actions such as elevating the importance of restoration.

Monitoring Forest & Shrubland Health

A major component of adaptive management includes monitoring to determine when there is need for updating site vegetation and condition assessments and the need for follow up treatments. Monitoring will allow information to update prescriptions, assess achievement of resource goals and objectives and direct necessary actions and timing. Regular quantitative assessments of forest and shrubland health should include metrics relevant to pollinators. For example:

- Incorporate quantitative assessments of floral resources and the richness, abundance, and diversity of pollinators into monitoring protocols.
- Include management objectives to include and maintain important woody resources such as snags, rotting logs, and brush piles.
- Evaluation of the site after restoration to determine if additional restoration measures and seeding of native plants will be necessary.

Tree & Brush Recommendations for Built Environments

Roadsides

Along roadways that stretch into forested or shrubland areas, trees and brush may be removed from the adjacent roadside to address problematic shrubs and trees. Trees and shrubs along roadways may be problematic

> "Usually we won't take more than 60% of a stand and we leave it in a mosaic fashion with fuel breaks. The goal is to have as little ground disturbance as possible. The machinery you utilize makes a big difference. We try to make it look patchy, have a lot of age classes, diversity, and be a resilient forest community."
>
> - Colorado Native Pollinating Insects Health Study Agency Interview Participant

for safety and fire mitigation reasons or because of other maintenance risks. Selective pruning or thinning to partially remove woody vegetation along roadways can benefit pollinators by creating opportunities for wildflowers to grow. The complete removal of trees and shrubs is not always beneficial because of the benefits to pollinators provided by woody vegetation. When possible, consider leaving snags or trees with cavities in areas where they are set back from the road and pose no safety risk. Transitional areas between forest and grass can be created by using brush removal to feather or soften forest edges adjacent to the recovery area. Periodic cutting to maintain healthy growth and an open canopy benefits remnant patches of grass, wildflowers, forest, or other habitat dominated by woody vegetation; improves the quality of the habitat for pollinators and many birds; and is aesthetically pleasing.

Feather or soften forest edges. In forested areas adjacent to roadways and beyond the vehicle recovery area or safety zone, feather or soften the forest edge through selective thinning practices to create a transitional area between trees and grass.

Leave snags or trees with cavities. In areas where they are set back from the road and pose no safety risk, retain tree snags and trees with cavities.

Additional Resources

Pollinator Habitat Conservation Along Roadways
NASEM; TRB; NCHRP

- Volume 12: Northern Plains Region
  nap.nationalacademies.org/catalog/27088/pollinator-habitat-conservation-along-roadways-volume-12-northern-plains
- Volume 13: Rocky Mountains Region
  [...]/27121/pollinator-habitat-conservation-along-roadways-volume-13-rocky-mountains
- Volume 15: Southern Plains Region
  [...]/27119/pollinator-habitat-conservation-along-roadways-volume-15-southern-plains
- Volume 16: Southwest Region
  [...]/27118/pollinator-habitat-conservation-along-roadways-volume-16-southwest

Landscaped Areas and Other Sites with Trees and Shrubs

Trees and shrubs are often planted or managed as part of the landscaping around buildings, offices, facilities or in other spaces managed by state agencies. As highlighted in the overview section, trees and shrubs can be important for pollinators for forage, shelter, and nesting. Establishing both native trees and shrubs in landscaped areas, and retaining those that are existing, will add to the diversity of resources available for native pollinators.

Plant and maintain native trees and shrubs. There are a range of factors that must be considered in choosing trees or shrubs appropriate for landscaped areas. Prioritizing native species that provide forage, nesting, and shelter resources for native pollinators and those that bloom at different times than available flowering plants will enhance the area's value as pollinator habitat. Many flowering trees and shrubs bloom early in the spring and can provide an important source of nutrition for overwintered pollinators that emerge in the spring. Planting trees and shrubs in areas with more impermeable surfaces can also contribute to shade and cooling, while providing valuable resources for pollinators.

When possible, leave standing snags, logs, brush piles, and hollow- or pithy-stemmed shrubs. In landscaped areas, leaving areas a little "messy" by having logs, brush piles and woody-, hollow-, or pithy-stemmed vegetation as part of landscapes and keeping ground litter intact is important for pollinators. These materials can often be used by native bees (as well as syrphid flies, soldier beetles, and a host of other invertebrates) to overwinter. If leaving snags does not pose a hazard, retain them. Stem- and wood-nesting bees will take advantage of any hole of the preferred size for them. Butterflies that overwinter as adults include anglewings (*Polygonia* spp.), tortoiseshells (*Aglais* spp.), and the mourning cloak (*Nymphalis antiopa*). These butterflies tend to take shelter in both natural and built areas, including tree cavities, under logs or rocks, behind loose bark, within evergreen foliage, or tucked into stone walls, buildings, and fences.

Retain and restore native woody species in wetlands and riparian areas. Prioritize retaining and restoring important native riparian woody species that support pollinators. Some examples that broadly apply include native willow (*Salix* spp.), rose (*Rosa* spp.), elderberry (*Sambucus* spp.), currant (*Ribes* spp.), and cherry (*Prunus* spp.).

Additional Resources

Nesting & Overwintering Habitat, for Pollinators & Other Beneficial Insects
Xerces Society for Invertebrate Conservation
xerces.org/publications/fact-sheets/nesting-overwintering-habitat

Pollinator-Friendly Parks: Enhancing Our Communities by Supporting Native Pollinators in Our Parks
Xerces Society for Invertebrate Conservation
xerces.org/publications/guidelines/pollinator-friendly-parks

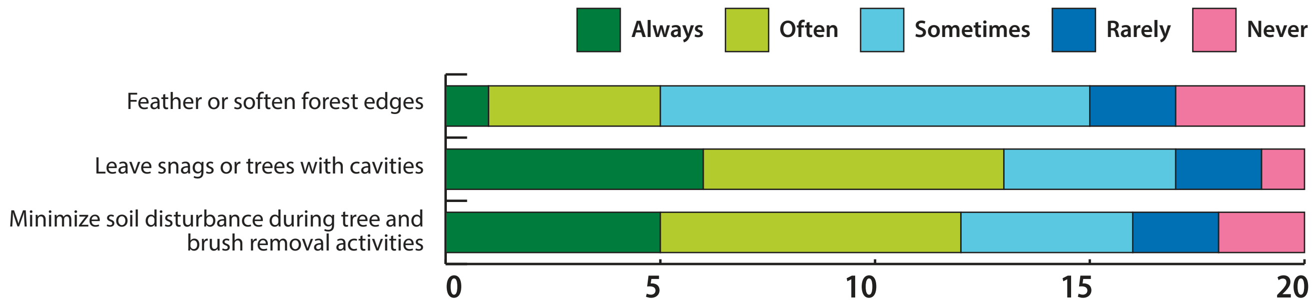
State Pollinator Conservation Tree & Brush Removal Practices

The survey of state staff provided information about how often different pollinator-oriented land-management practices are used. Over two thirds of the survey participants indicated that their agency was involved in tree and brush removal practices. The state agencies that use or have lessees who do forest thinning and fuel reduction related work are CPW, SLB, CDOT, and Colorado State Forest Service (SFS). Among these agencies, the frequency of use tended to be fairly common (sometimes, 16%; often, 37%; and always, 8%).

Three specific tree and shrub thinning practices that relate to pollinator conservation were further evaluated in the survey. The most frequently applied practice was leaving snags or trees with nesting cavities. The next most common practice was minimizing soil disturbance during removal activities, and the least implemented practice was feathering or softening forest edges.

Figure 3.12 (below) shows the relative frequency that the agencies implement these three practices. Of the three practices, feathering or softening forest edges is a practice that has the greatest potential to be more regularly integrated into management practices, as it was repeatedly identified as a practice that was only "sometimes" applied. These practices should be included in operational maintenance manuals or in forest management prescriptions to improve pollinator habitat, and generally be more commonly used whenever possible.

Figure 3.12: How frequently does your agency currently implement the following tree/brush removal practices?



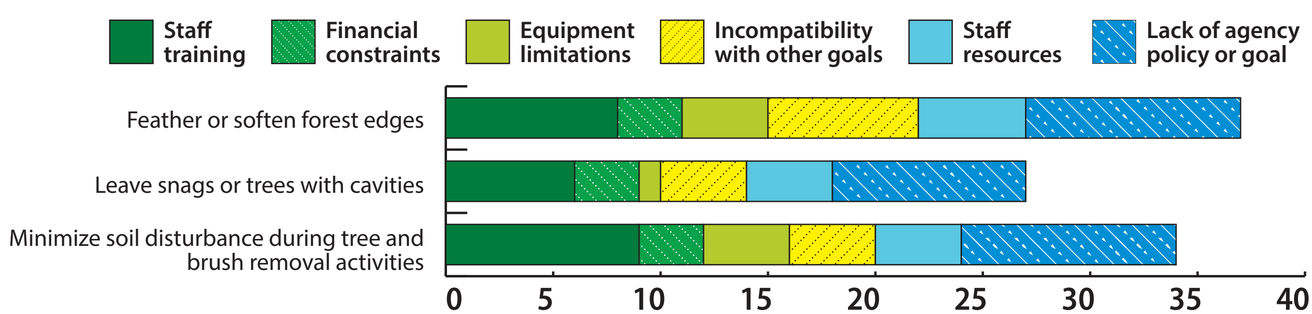
Challenges & Barriers to Implementing Pollinator Tree & Shrub Removal Practices

Staff identified several barriers that are encountered and hinder efforts to implement more frequently the three potential pollinator conservation practices. Survey results about barriers experienced by staff are available in Figure 3.13 (below). The most common barriers identified by staff include:

- Lack of agency policy or goal, and
- Lack of staff training.

A common theme that has emerged across various pollinator practices is the lack of agency policy direction or guidance related to integrating pollinator conservation into management practices, and a corresponding lack of staff training. Establishing policy goals that identify the importance of including pollinator-related practices into management actions can result in the prioritization and adoption of relevant practices. To highlight this aspect, interviews with CDOT staff clarified that the existing manual of maintenance does not currently include guidance around leaving snags or trees with cavities and feathering forest edges, but these practices were thought to be helpful practices that could be added. Agency policy directives or goals emphasizing the importance of integrating pollinator practices into operational manuals would therefore likely prioritize the inclusion and adoption of such practices.

Figure 3.13: What are the barriers for your agency to implement the following tree/brush removal practices?



The other potential barriers, including lack of staff resources, equipment limitations, financial limitations, and incompatibility with other goals, appear to be less of a challenge. Interviews with staff helped to clarify that these practices for the most part are compatible with existing practices and forest management.

3.2.4. Grazing & Rangeland

Colorado has extensive and very diverse rangelands throughout the state that support the agricultural economy while also supporting important habitat for pollinators. These rangelands have very diverse landscapes and rangeland plant communities, from shortgrass prairie in the Eastern Plains, to sagebrush steppes, to canyonlands, and montane and subalpine grasslands in the mountains. Colorado's prairie grasslands have evolved historically with large ungulate grazers (bison, elk, pronghorn, and deer), and prescribed grazing with domestic livestock can approximate, to some extent, this type of grazing and may be essential as a tool for supporting healthy functioning plant communities and to promote biodiversity, including pollinator diversity (Kohl et al. 2013; Tonietto and Larkin 2018). As a result of the diverse rangeland landscapes, there can also be a high variation in preferred grazing regimes.

Rangelands can support a broad diversity of pollinators because they provide food, nesting resources, and host plants. Grazing can be a useful management tool for maintaining the open early seral landscapes important for many butterflies and other pollinators. Grazing can also provide vegetative structural diversity and encourage the growth of nectar-rich spring and summer flowering plants (Vanbergen et al. 2014). Grazing can also limit tree and shrub invasion. Well-managed rangelands also have particular value to certain species of pollinators that only exist in remnant native grassland habitat.

Establishing detailed or prescriptive grazing practices for rangelands that benefit pollinators is best done within the context of the ecology, landscape, and management goals of a specific rangeland. There are, however, grazing principles and practices that provide overarching guidance and can be integrated into site-specific prescriptions to foster more suitable rangeland conditions for pollinators and potentially other wildlife.

In general, to support pollinators, the arid and semi-arid rangelands common to Colorado should be managed using adaptive planned grazing or regenerative grazing principles that consider the timing, intensity, duration, and recovery period needed to support pollinators. If rangelands experience grazing pressure during some or all of the seasons with the greatest activity for most pollinators—generally May to September, but see Figure 3.4. Recommended Management Timing for Native Bees in Western North America for more information—this can reduce the availability of floral resources for pollinators. It may also tend to homogenize the landscape and may not allow vegetation and pollinator refuges or sufficient time to recover. Varying the timing of grazing events from year to year between the growing (April–Sept) and dormant (Oct–March) seasons can help minimize the long-term impact on plant communities. Season-long summer grazing is especially problematic if it occurs at the same time and place every season, which eventually limits plants' ability to set seed, and limits the recovery of plant communities from disturbance.

Pollinator-friendly regenerative grazing practices are those that consider grazing timing, intensity, duration, and recovery period and use all these factors as an adaptive planned grazing regime. As an example, rotational grazing practices can work as long as the timing, intensity, duration, and recovery period are factored in. For pollinators, ensuring the rest periods are long enough for the vegetation (including blooming flowers) and pollinators to recover is critical. Regenerative grazing also fosters healthy plant growth, leads to stronger roots, healthier soils, and facilitates increases in soil carbon sequestration.

When developing grazing management plans, include pollinator resources as management objectives. Development of a grazing plan that includes careful consideration of the type of grazer, its food preference, and how well it can be managed is important for managing compatibility with pollinators. As an example, livestock can be managed when they are brought onto a site and when they are removed for prescribed grazing to address a weed concern, thereby bracketing periods of time when pollinators and pollinator habitat may be least affected. Goats and sheep prefer broadleaf plants and therefore are the preferred grazers for sites where broadleaf weeds are an issue. Goats are also excellent grazers to use for arresting woody plant encroachment. Prescribed grazing for weed control is most effective, for example, when target weeds are palatable. Cattle have been used to target invasive annual grasses such as cheatgrass in the early spring prior to seed set and then removed to benefit native vegetation. It may also be important to factor into grazing plans considerations like when floral resources are already scarce, such as long periods of drought, and have contingency plans in place. Grazing during times when floral resources are limited can have a greater impact on pollinators over the short, and potentially, longer term. Additionally, the stocking density of grazers can help to determine the duration of grazing.

Figure 3.14. Prescriptive grazing with cattle using temporary fencing to manage the extent, duration, and timing of grazing. (Photo: K. M. Velis.)

A good goal for maintaining quality pollinator habitat is to strive for a diversity of as many flowering plant species as is possible in a site throughout the growing season. Range managers should also aim to prescribe grazing regimes that are compatible with maintaining or returning each site to its full complement of native plant species, which can be informed by looking at reference sites in the region. Maintaining good pollinator habitat is especially important if a grazing property has at-risk pollinators, sensitive habitats important for pollinators, or areas of high pollinator abundance or diversity. It is also relevant to consider that pollinators that overwinter above ground will be sensitive to grazing even beyond the frost-to-frost focus period. Therefore, one single grazing management system or prescription will never suit all pollinators, site conditions, or management objectives.

Recommendations for Grazing That Apply to Rangeland Landscapes

The following section includes several guiding principles and corresponding conservation practice recommendations that help inform how state rangelands and grazing can be managed to reduce impacts on and improve habitat for pollinators. Integrating these recommendations with rangeland conditions, rangeland management goals, and available management resources will be important to develop prescribed grazing plans that conserve pollinators.

Key Principles for Pollinator-Friendly Grazing

Principle 1: Forage Utilization and Grazing Intensity

An underpinning principle for pollinator-oriented grazing plans is establishing appropriate forage utilization (consumption and trampling) objectives. Planning for the stocking rate of livestock should ideally be based on the forage available while also ensuring adequate vegetation is left after grazing to maintain healthy range conditions and habitat for pollinators and other wildlife. Generally, as forage utilization increases, pollinators, including butterflies, moths, and other insects may decline in abundance and/or diversity in the short term, and even potentially in the longer term, if adequate recovery times are not provided. As an example, higher-intensity grazing needs to be paired with shorter durations, longer recovery times, and a rotational scheme, so that neighboring ungrazed or recovering units can provide functional pollinator habitat and refuge while grazing occurs. In some ecosystems, lighter or more moderate grazing can be an important tool for helping pollinators, as long as forage utilization thresholds continue to be maintained.

Principle 2: Adequate Recovery Times—Grasses and Wildflowers

Another core principle of prescribed grazing is allowing adequate recovery of grassland plants between grazing events (Tainton et al. 1977; Manske and Sedivec 1999). Sufficient recovery of highly palatable forage cannot be sustained with continuous season-long grazing on a single pasture or grazing unit without the stocking rate remaining very low. Typically, grazing plans are focused on recovery times for grasses, the primary forage species for livestock. However, livestock can also consume wildflowers due to their high nutrient contents. Many of these highly nutritious wildflowers are also important to pollinators and the time it takes for a wildflower species to recover and bloom may vary. To account for this, grazing season and duration should be adjusted so as to minimize negative impacts on wildflowers for pollinators. To learn what the necessary rest period is to allow plant recovery, consult local range management specialists.

Principle 3: Alternate Season of Use and Timing

The third key principle of prescribed grazing is alternating a unit's season of use, so that every unit is grazed at a different time from year to year. This helps increase plant diversity and vigor by safeguarding that cool-season and warm-season plants are not grazed the same time of year each year (Briske and Richards 1994). As an example, if a site is grazed every year during the critical growth periods of cool-season plants, eventually the cool-season plants could be grazed to the extent of not being able to persist and recover, and the site will change to a predominately warm-season plant community.

Principle 4: Adaptive Management

When implementing a prescribed grazing plan, it is important to monitor rangelands and adjust the grazing schedule as necessary to achieve management goals. Monitoring rangelands before, during, and after a grazing event can help to determine grazing readiness, the number of grazing days each unit can sustain, and extent of utilization, and identify other factors such as climate considerations that may influence grazing plans. Developing a grazing plan at the beginning of each grazing season is an essential step, but a grazing plan should only serve as a guideline for implementation throughout the season. It is also essential to monitor the grazed rangeland to assess the condition, utilization levels, species present, precipitation events, and vigor of each site so that there can be adjustments and changes to the plan as needed during the grazing season.

Even though the grazing is a common use of native rangelands in Colorado, unfortunately, there has been little research done on the effects of grazing on wildflowers and pollinators in the state. Because of the lack of such information, and because of the many variables involved (topography, climate, soils, etc.), it is difficult to provide best management practices that would apply to all of the state's rangelands. Therefore, rangeland managers can cope with that uncertainty by using an adaptive management approach to maximize floral production for pollinators while also addressing the needs of grazing operations. Given the diversity of insect pollinators, and the challenge in identifying them, few range managers will have the capacity to monitor pollinator communities. It is much easier to monitor the abundance of key floral resources. Seeking technical assistance from local range-management specialists, pollinator experts, Natural Resources Conservation Service staff, and regional vegetation experts to discuss the specifics of a rangeland unit when trying to plan pollinator-friendly grazing is incredibly valuable and important, especially to be more effective with adaptive management.

Recommended Grazing Practices for Pollinators

The following best practice recommendations are organized by the key principles.

Carefully Manage Forage Utilization Rates and Grazing Intensity

Plan utilization rate based on the type of natural community and management goals. Managers should determine utilization levels depending on management goals and also adaptively manage based on current plant community and plant community goals. Consult local range-management experts (e.g., NRCS, conservation districts) for guidance on the range of utilization rates that will help achieve the goal of moving each ecological site back to its reference condition. It is also important to consider the type of livestock being grazed, as stocking rates and management strategies should account for the preferred forage of the particular livestock when feasible. Land managers should work closely with local rangeland managers, wildlife biologists, and botanists to determine site-specific percent utilization and stubble heights that will maintain forb diversity and abundance for pollinators from frost to frost. A mosaic of lightly, moderately, and heavily grazed areas may be needed to maximize or improve diversity across some landscapes.

Use even lower utilization rates in mesic meadows, springs, and riparian areas and in times of drought. Utilization rates should be determined on an annual basis for mesic meadows, springs, and riparian areas and in times of drought because drought, grazing history, and native ungulate use all affect utilization rates. Utilization rates in these habitat types should generally be less than the surrounding xeric landscape. Place fencing along riparian areas and use "water gaps" to locate and provide access to stream or riparian areas for livestock water.

Plan for low-intensity use for season-long grazing. Use low intensity (low Animal Unit Months [AUMs] for site or allotment) for season-long grazing or rotations that exceed 45 days in any single pasture or management unit. For smaller operators, consider opportunities to join with other small operators in the area to combine herds, so that smaller pastures can have longer recovery times.

Recovery Periods Are Essential

Ensure rangelands are provided sufficient recovery times. Ensure grazed areas are provided sufficient rest times to allow vegetation, especially native grasses and wildflowers, to recover before being grazed again. Stocking rates and duration should be appropriate for the characteristics of a site, livestock species, and management objectives. Recovery periods will also vary depending on the amount of recent precipitation or moisture received in a given area or season. Be prepared for drier conditions stressed by a lack of precipitation, and have a drought management plan that prepares ahead of time for necessary destocking in the event of drought conditions, thus minimizing long-term impacts to arid rangelands.

Timing of Grazing Matters

Time grazing to avoid vulnerable life stages of pollinators and flowering plants. Fall and winter grazing have the least impact on pollinators because most plants and pollinators are least active in winter. To do that, however, soils must be able to withstand late-season or winter grazing. If feasible, adjust grazing time to fall or winter on some grazing units when most flowering plants are dormant and pollinators are least active. This is one strategy to take pressure off plants and pollinators, but it may not be possible on all grazing units managed by an agency or lessee. Another strategy is to avoid grazing the same location at the same time every year (e.g., alternate the timing of grazing within an allotment)

- Some parts of the state may be more suitable for ranchers to rest their rangeland in the summer due to drier conditions or drought. In other parts of the state, resting in summer is more difficult to accomplish and significant amounts of summer rest can be provided through a rotational system (for instance, putting cattle in one pasture in the first year, and then moving the cattle to a second pasture in year two).
- Sheep grazing on conservation lands should occur in the fall and winter after flowering plants have senesced. If sheep grazing must occur during peak pollinator activity (May–September), the sheep should be introduced at low stocking rates and floral resources should be monitored to avoid depleting them over time

Figure 3.15. Regenerative grazing practices are especially important for grazing sheep when flowers are present to avoid the loss of flowers that would otherwise be used by pollinators. Here the flowering head of a little sunflower (*Helianthella quinquenervis*) is about to be eaten. After several years of heavy grazing, the once-common sunflowers have almost disappeared from this meadow at Horse Ranch Park in Gunnison County. (Photo: David Inouye.)

Time grazing to avoid large blooms of annual flowers. In more arid regions of the state, there may be a large flush of annual flowers after a high precipitation event or flood. Similar concentrated bloom events can occur after spring snowmelt in high-elevation meadows. In both habitats, adjusting the timing of grazing can ensure ephemeral flowering plants have time to set seed and pollinators present in the area can use the plants as nectar resources.

Time grazing to avoid vulnerable life stages of imperiled pollinator species. If rare or imperiled pollinators are present, time grazing to minimize overlap with breeding and foraging periods. For imperiled butterfly or moth larvae that have host plants palatable to the type of livestock being grazed, avoiding grazing when larvae are feeding on host plants reduces the effect on these pollinators.

Use rotational grazing. Implement rotational grazing schemes when feasible. Install wildlife-friendly permanent fencing or moveable fencing so that livestock can be rotated through pastures or management units to allow recovery of the vegetation and to keep livestock out of any overutilized or sensitive areas. If fencing is not an option, rotational grazing can be possible often with some ingenuity such as using natural barriers (topography that limits livestock movement), herders, water, salt blocks, or nutritional supplements to keep livestock in desired areas and away from areas deemed important for pollinators, sensitive wildlife, or plants. For every paddock or bounded area that is grazed, a corresponding recovery period needs to occur and be integrated into the rotational scheme. The rest period helps plants to recover from a grazing event, maintains habitat heterogeneity, avoids overutilization of any given area, and maintains floral resources for pollinators.

- **Prescribed grazing for weeds.** Graze during peak growth of target weeds or undesirable vegetation; use high-intensity, short-duration grazing at the targeted time periods and rotate grazed sites. Doing so will help to open up the site and increase plant diversity.
- **Rotate sheep more frequently.** Sheep should be herded regularly and rotated through different pastures trying to also avoid rotation into adjacent pastures. Sheep should not be allowed to graze one location longer than one to two days, and floral resources should be closely monitored to avoid depleting an area of flowering plants during peak insect forage and breeding seasons.

Practice Adaptive Management

Develop adaptive management and flexible grazing plans. Flexible, adaptive planned grazing is key to maintaining long-term forage for grazing animals and habitat for wildlife, including pollinators. Grazing management plans should be site-specific and flexible in order to adapt stocking rates, timing, and duration to changing environmental conditions, which include, but are not limited to, a depletion of pollinator resources (flowering or nesting plants), overutilization, drought, fire, and invasive species. Flexible management plans should allow adjustments to prevent depletion of important floral resources for pollinators generally and especially if there are specific targeted rare or imperiled pollinators that need to be considered. This will vary annually as well as by regions within the state, elevation, habitat type, and season. The following are special circumstances that should require adaptive management.

- **Over-utilization.** After heavy grazing or over-utilization occurs, livestock should be excluded from the area for at least a growing season to allow the habitat time to recover. The length of the rest period needed will vary by location and site conditions.
- **Drought.** Grazing during drought can deplete already scarce floral and host plant resources for pollinators. Adjust grazing intensity and duration to account for drought conditions, and avoid depleting already scarce floral resources.

Monitoring rangeland health for pollinators. A major component of adaptive management includes careful vegetation monitoring to determine when grazing intensity, duration, and timing should be adjusted. This should be implemented at semiannual intervals, ideally, or more frequently. Regular quantitative assessments of rangeland health should include metrics relevant to pollinators. For example:

- Incorporate quantitative assessments of floral resources and/or pollinator abundance into existing range utilization monitoring.
- Include management objectives to achieve healthy rangelands for pollinators, such as a minimum of three (ideally more) species flowering at a single time throughout the frost-to-frost growing season.

Landscape-scale considerations. Include resilience and resistance concepts into grazing management programs. Resilient and resistant rangelands are less likely to be converted to annual invasive grasslands after disturbance events. This approach is being used for greater sage-grouse conservation and is widely applicable to pollinator conservation (Chambers et al. 2017).

- Stock livestock at a duration, timing, and intensity that will maintain existing conditions in areas identified as high priority, resilient, and/or resistant to habitat stressors such as fire, invasive species, and drought. This is especially important in rangelands that are under threat of being invaded by cheatgrass (*Bromus tectorum).*

Additional Resources

Rangeland Management and Pollinators: A Guide for Producers in the Great Plains
Xerces Society for Invertebrate Conservation
xerces.org/publications/fact-sheets/rangeland-management-and-pollinators

Best Management Practices for Pollinators on Western Rangelands
Xerces Society for Invertebrate Conservation
xerces.org/publications/guidelines/best-management-practices-for-pollinators-on-western-rangelands

Bird Conservancy of the Rockies Best Management Practices for Grassland Birds
Bird Conservancy of the Rockies
www.birdconservancy.org/wp-content/uploads/2017/03/Bird-Conservancy-BMP-for-Grassland-Birds-CSLB.pdf

State Pollinator Conservation Grazing Practices

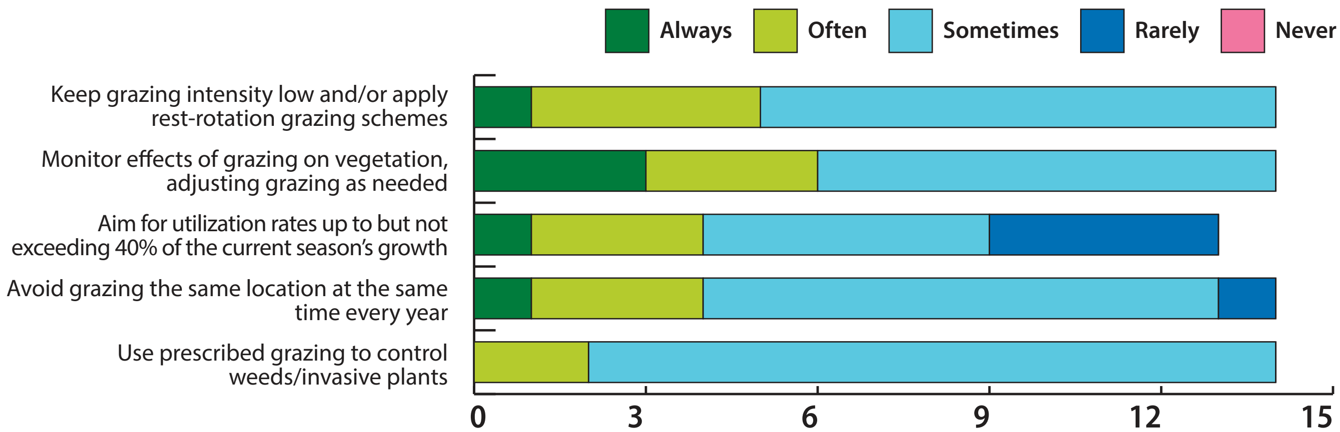
The survey of state staff assessing the frequency of use of various land-management practices resulted in responses that indicated grazing wasn't applicable for nearly half of the survey participants. Prescribed grazing is a relevant land-management practice for state-managed rangelands or on lands leased out for someone else to manage for two agencies, CPW and SLB. For those agencies, the frequency of use tended to be more common (sometimes, 17%; often, 31%; always, 3%).

The survey responses identified the pollinator-supporting grazing practices that are most or least commonly used by state agency:

- Most implemented were monitoring the effects of grazing on vegetation and keeping grazing intensity low.
- Moderately implemented were adjusting grazing when needed and avoiding repeat grazing of the same location at the same time every year.
- Least implemented were keeping utilization rates below 40% and weed control using grazing.

Figure 3.16 (below) indicates the frequency at which state agencies currently implement conservation grazing practices that support pollinators.

Figure 3.16: How frequently does your agency currently implement the following prescribed grazing practices?



A survey question focused on the feasibility of adjusting grazing regimes such as timing, intensity, stocking rates, and duration indicated a higher potential for being implemented (medium, 23%; high, 21%) than not (8%). Overall, the survey results suggest that adjusting and managing grazing practices to benefit pollinators may be desirable and applicable on many of the rangelands for which the state is responsible. An important point that was raised during staff interviews was the opportunity for the state to be a leader in demonstrating the benefits of well-managed grazing practices which could then have a spill-over effect to private rangeland management. A significant contributor to this could be the SLB with over two thousand grazing lessees. With all of the practices being predominantly "sometimes" used, the survey results suggest there are opportunities for using more of these practices more frequently, which would result in conservation benefits for pollinators and likely other ecological gains.

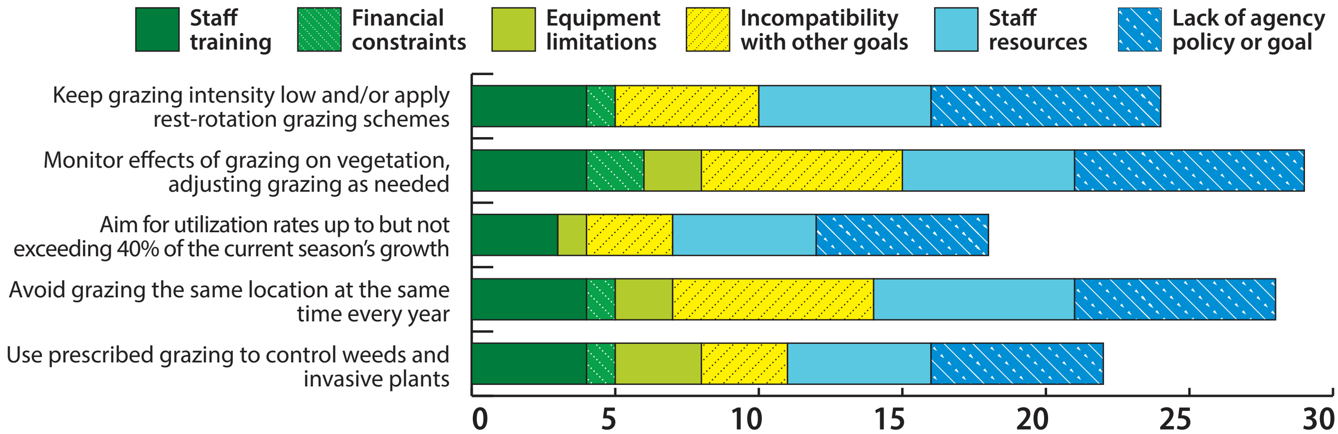
Challenges & Barriers to Implementing Pollinator Conservation Grazing Practices

Barriers exist that can make it challenging to implement some or all of the pollinator-oriented grazing practices. The state survey assessed several commonly encountered barriers to help identify those that may be most relevant and important to understand and address. The survey results are available in Figure 3.17 (next page) and show that four of the barriers are more noteworthy impediments, and therefore, more important to consider and address. These are:

- Lack of agency policy or goal,
- Lack of staff training,
- Incompatibility with other goals, and
- Lack of staffing resources.

The lack of clear pollinator-oriented grazing management goals showed up on the survey as the most common, and therefore, the most important impediment to address. The importance of having focused goals and policy addressing pollinator conservation would also likely help address issues associated with conflicts with other management goals, another prominent barrier according to the survey results. Interviews with staff reinforced that without policy support, a corresponding push to adjust and implement new practices is unlikely to occur. The staff interviews further highlighted that not having clear goals and guidance for grazing practices can result in practices that are highly variable, may be influenced by local politics or perspectives, and potentially based on incomplete grazing plans or limited information—and may not address wildlife or pollinators.

Figure 3.17: What are the barriers for your agency to implement the following prescribed grazing practices? Select all that apply.



The lack of staff training about range-management practices shows up as an important challenge, and as previously discussed in the mowing section, often aligns with not having adequate policy and procedure guidance. The lack of staffing resources has implications, as implementing prescriptive plans will likely require attention to logistics, such as making sure necessary fencing, exclosures, and livestock movement can be managed. Staff interviews brought up this aspect when pointing out that the prescriptive use of livestock for the control of weeds is desirable and popular with the public, however the logistics to manage are significant in terms of fencing, managing livestock grazing patterns, finding the right vendors, contract or lease requirements, having the flexibility to adjust, and year-to-year variations. Additionally, monitoring and adaptive management require staff time, training, and then the flexible availability of field staff to make grazing adjustments as needed.

Leased-out rangelands, as is the case for many SLB properties, may also present challenges as lessees often determine and carry out grazing management. While staff encourage lessees to undertake conservation-grazing practices, implementation of practices remains at the discretion of lease holders. Integrating pollinator practices into educational information shared with lessees and potentially giving preferences to leases that integrate conservation practices or developing policy to prioritize pollinator conservation for areas with the highest pollinator-conservation value could be approaches to reduce this barrier. For lands where imperiled pollinators occur or include particularly high-quality pollinator habitats, building specific pollinator-conservation prescriptions into the lease specific may be a way to ensure pollinator health is protected in these important habitats. Some of the operational barriers lessees may face are due to being smaller operators and thus limited in size, and may lack ranch infrastructure (fences and livestock water systems) to implement rotational or regenerative grazing practices. Considering approaches to incentivize the implementation of pollinator conservation practices may also be beneficial to consider. The SLB has the ability to evaluate and award leases to applicants with high stewardship qualifications in both their competitive grazing bid and RFP processes. The stewardship qualifications should be heavily considered and ideally integrate pollinator habitat considerations.

3.2.5. Integrated Pest Management & Pesticide Risk Reduction

Integrated Pest Management & Pesticide Risk Reduction

The management or control of unwanted or harmful plants and animals, including insect pests, through the use of pesticides (insecticides, fungicides, herbicides) can have unintended lethal and sublethal consequences for pollinators (Longley et al. 1997; Cousin et al. 2013). Herbicides, used to remove unwanted vegetation or invasive weeds, are the most common type of pesticides applied through state land management practices; Section 3.2.6 is devoted to weed management and herbicide recommendations. State use of pesticides other than herbicides—insecticides, fungicides, and potentially, other pesticides—appears to be more limited, based on survey and interview results. However, given the potential risks of pesticide exposure to pollinators and their habitats, this section of the report provides a broad overview of the impacts of pesticides to pollinators and general guidance around pesticide use.

When state agencies need to respond to pests, having an existing management framework helps to ensure a safer and more effective response. State agencies that oversee pest management activities can develop integrated pest management (IPM) or integrated pest and pollinator management (IPPM) plans to guide decisions. (For example, each state park has an integrated weed management plan that is updated regularly and is based on site-specific mapping.) At its core IPM is a process to address and prevent pest problems, while minimizing risks to people and the environment. An IPM or IPPM framework involves:

- Preventing conditions that favor pests (e.g., Removing plants that serve as an alternate host for a particular pest),
- Establishing thresholds at which pest management actions should be taken to avoid economic loss or a particular level of damage,
- Monitoring of pests or damage to determine when or if thresholds have been met, and
- Targeted pest management, which evaluates possible options but prioritizes the least hazardous methods, when pest management is warranted.

Pesticides may be part of a management plan, in which case mitigation steps are taken to limit potential unintended consequences.

The degree to which pesticides cause harm to pollinators is influenced by the toxicity of the pesticide and the level of exposure. Pesticides can kill pollinators outright or they can inflict sublethal harm, such as reducing a pollinator's ability to find food or navigate, reducing reproduction, or altering development or survival time. Insecticides, which are formulated to target insects, pose the greatest risks for pollinators; many insecticides are broad spectrum and kill nontarget species as well as the intended pests. For example, aerial applications of insecticides for mosquito control, such as adulticides like naled and permethrin, kill or harm a wide range of species (Mazzacano and Black 2013), including caterpillars and adult butterflies exposed to contaminated foliage

Figure 3.18. Spot-spraying of herbicides using a backpack sprayer to manage Canada thistle and bindweed in Glacier National Park. (Photo: National Park Service.)

(Hoang and Rand 2015; Braak et al. 2018). Carbaryl, a broad-spectrum insecticide, is often used for treatments to prevent mountain pine beetle impacts to high-value trees in Colorado, and may be applied over large areas, with impacts to nontarget species. Carbaryl and diflubenzuron have been used over large acreages to suppress native grasshoppers and Mormon crickets in grasslands (e.g., Hewitt and Onsager 1983). Large-scale aerial applications on natural lands can reduce bee abundances (Graham et al. 2008), and subsequently the pollination services they provide (Kevan 1975). Evaluating all potential management options for insect pest control within an IPM framework can reduce excessive insecticide use.

Fungicides can also negatively affect pollinators. Fungicides have been linked to adverse effects to bees, impacting development, behavior, immune response and reproduction (Zhu et al. 2014; Bernauer et al. 2015; DeGrandi-Hoffman et al. 2015). Some fungicides can make bees more susceptible to damaging parasitic fungal infections (Wu et al. 2012; Pettis et al. 2013). Furthermore, in situations where a combination of fungicides and insecticides are used, fungicides increase the toxicity of some insecticides (Siddartha and Revannavar 2014; Tsvetkov et al. 2017). Employing non-chemical disease prevention and management is a valuable first line of defense. The consideration and use of any type or combination of pesticides should be carefully vetted through an IPM or IPPM process.

Colorado's Department of Agriculture (CDA) has developed a Managed Pollinator Protection Plan, geared towards pesticide applicators. The plan supports the use of IPM and provides guidance on reducing the risk to managed pollinators from pesticide use. Communication between beekeepers and pesticide applicators is an important component of the guidance. When applicators know about locations of apiaries, they can take certain precautions to reduce exposure to honey bee colonies. Beekeepers that voluntarily enroll their apiaries with BeeCheck (a mapping tool related to FieldWatch and DriftWatch) can help inform pesticide applicators of apiary locations. However, the risk-reduction recommendations in the plan that are dependent on locations of apiaries and colonies are not applicable to wild pollinators that reside permanently within all landscapes and cannot be temporarily restrained within their shelter to avoid pesticide exposure as with managed bees.

Pollinator Exposure to Pesticides

Pesticide toxicity is an important component of the risk assessment to consider when evaluating the need to use a particular pesticide. It is important to prioritize the use of active ingredients that are the least toxic, considering all life stages and the potential routes for exposure to pollinators. Pollinators can be exposed to pesticides through multiple pathways.

- **Direct Contact Exposure.** Direct contact is the most obvious pathway of exposure from a pesticide application which can occur when a pollinator such as a bee visits a flower in the same area where a pesticide is or has recently been applied. This exposure is a high-risk exposure for pollinators.
- **Residual Contact Exposure.** Pollinators can also come into contact with pesticides days after a pesticide has been applied. Some pesticides are formulated to break down more quickly, while others may be designed to persist longer in the environment. The pesticides that have higher residual toxicity may present additional risks for pollinators as they forage in an area with pesticide residues. Understanding the persistence of a pesticide is therefore helpful to avoiding harmful and unintended exposures.
- **Contaminated Forage.** Insecticides that can move through plants, systemic chemicals such as neonicotinoids, can also end up in the pollen and nectar of flowers. The drifting of pesticides from where they may be applied to nearby flowers can also result in the contamination of pollen and nectar. If bees forage on contaminated flowers, this can result in the transfer of pesticides back to the nest to

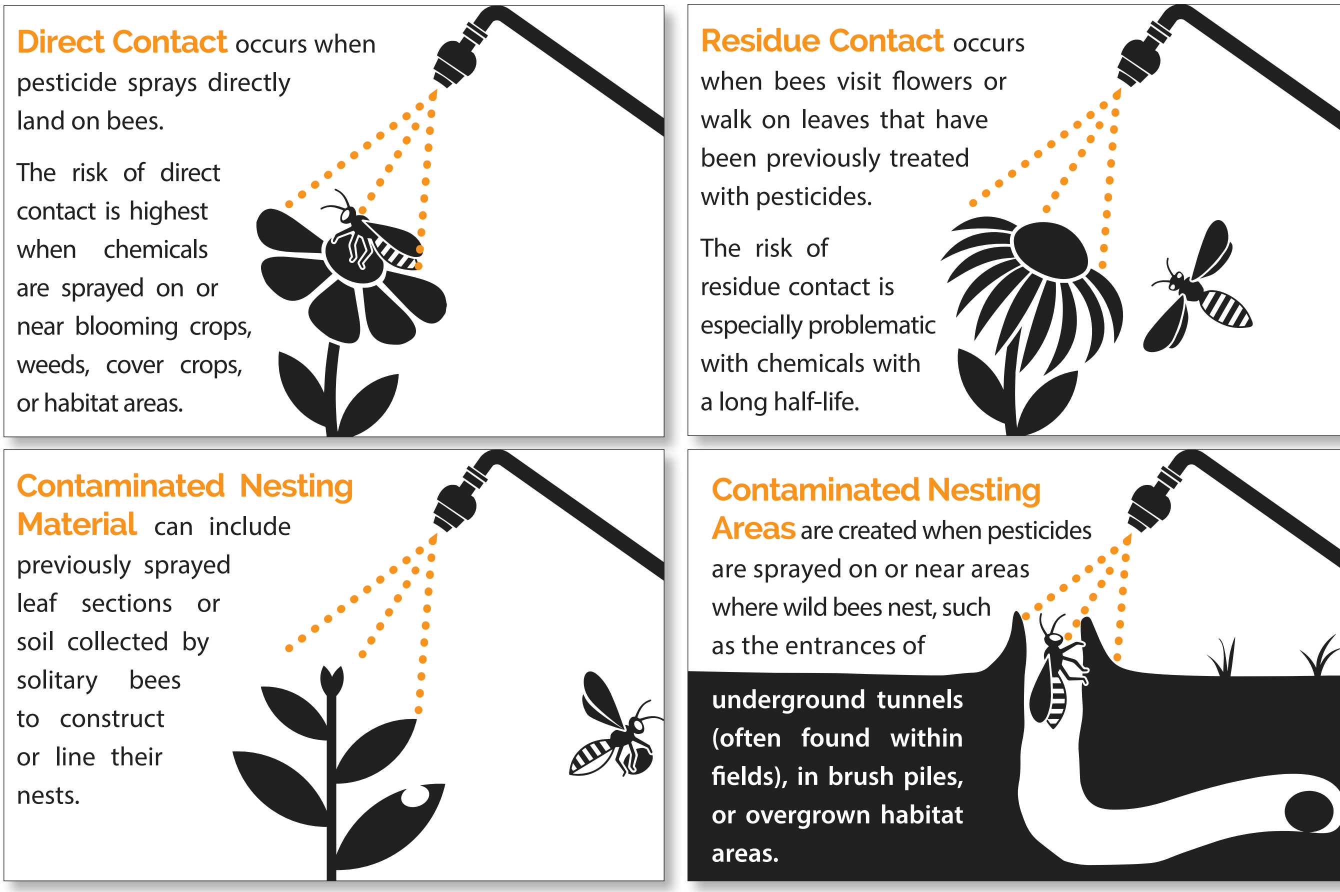


Figure 3.19. Graphic showing four pesticide exposure pathways for pollinating insects including direct contact, residue contact, contaminated nesting material, and contaminated nesting areas. (Graphic: Xerces Society.)

feed developing larvae which can harm the next generation. The caterpillars of moths and butterflies can also be at risk from host plants with pesticide residues remaining on (or in) leaves.

- **Contaminated Nesting Areas or Materials.** Native bees use a variety of materials in the construction of nests, including mud, leaves, plant hairs, and plant resins. The application of pesticides could contribute to the contamination of nesting materials used by bees when building nests. For ground-nesting bees, soil contamination can be particularly problematic (Chan and Raine 2021). Tunnel-nesting bees, such as leafcutter bees, use leaves to partition cells in their nests. If these leaves are contaminated they could expose the female as well as her offspring.

Guidance to Consider Around Integrated Pest Management & Pesticide Use in All Landscapes

The following guidance is intended to only be a starting point, broad guidance to consider when making management decisions around the potential use of pesticides and pollinator protection. Refer to Section 3.2.6 Integrated Weed Management and Herbicide Recommendations for more specific information about herbicide considerations and recommended practices. We recommend that Colorado initiate a more detailed assessment of how state agencies use pesticides other than herbicides in order to understand potential risks and design specific pollinator-conservation practices.

Identify and monitor for pests. Having information that identifies early on that a pest problem exists, the scale of the problem, and which way the problem is trending is incredibly important. Pest monitoring, preferably using verified methods, is the best way to make sure this information is available. The use of a pesticide should only be considered once the presence of a pest population has been determined to have reached a previously established threshold or criteria that supports the need for the use. Knowing information about the pest and when it's most vulnerable and susceptible to control will help determine the best management method.

Incorporate non-chemical prevention and management strategies. Prioritize management actions that focus on prevention and early intervention. Strategies to discourage pest proliferation and/or limit conditions that favor problematic insects are a first line of defense. For example, by encouraging landowners to take proactive steps to remove human-caused stagnant water where mosquitoes can breed. In some instances, the creation of habitat for beneficial insects can also help manage pests as well-designed floral plantings can attract natural enemies of pest insects, a practice called conservation biological control.

Reduce risk by selecting targeted short-lived and least-toxic pesticides. The level of toxicity, the persistence, and the selectivity of a pesticide impact the potential risks to pollinators. To reduce the risk to pollinators, establish a preferred list of least-toxic (and preferably selective and short-lived) pesticides and the pests they are most appropriate to target. Prioritizing organic pesticides may be a helpful approach, though some organic pesticides are still quite toxic to pollinators. Additionally, consider maintaining a list of prohibited or otherwise restricted pesticides (See the Bee Precaution pesticide rating tool listed in Additional Resources below).

Implement cultural, mechanical, physical, and biological prevention and management techniques. Cultural controls disrupt the environment depriving pests of harborage or limiting their spread. Mechanical and physical controls include barriers, traps, and other techniques to either kill pests or make an environment unsuitable for them. Biological controls are the use of natural enemies to control pest populations. The creation of pollinator habitat can also support and increase natural enemy populations providing free pest-control services.

Reduce and mitigate risks if pesticides are used. There are numerous ways to mitigate the risks of pesticides. Some examples include:

- Avoid aerial applications, especially of liquid insecticides, wherever possible to reduce the opportunity for drift or off-site movement.
- Use targeted methods such as baits, spot spraying, and other techniques that ensure a higher percentage of the pesticide used reaches the target pest.
- Make applications when environmental conditions are least likely to lead to off-site movement of particle or vapor drift.
- Plan the timing of applications to minimize or prevent direct exposure for pollinators, such as when flowers aren't present.
- Mowing to remove flowers from an area that will be treated could help minimize exposure.
- Ensure staff and contractors are trained to recognize both the pests that are being targeted, and to know what plants or vulnerable pollinator sites like bee nest sites to avoid.
- Avoid prophylactic applications.
- Follow the recommended application rates and all advisory language on the label; the label is the law.

Develop and be accountable to IPM or IPPM plans. Making pest management decisions by assessing effective alternative and least-harmful practices can be guided by advanced efforts to document management objectives, goals, and commitments through a formal pest management and pollinator conservation policy. The greater the detail in plans and operational procedures, the better they will be to ensure more thorough and complete evaluations of options and chosen practices are implemented by staff and contractors. Including IPM or IPPM procedures and practices in contracts with service providers will also ensure contractors follow the established recommended best practices. Prioritize training, and reinforce the importance of continued learning, safety, and mitigation practices. IPM or IPPM plans should be living documents, updated as practices are evaluated and adaptive management occurs.

Additional Resources

Colorado Managed Pollinator Protection Plan Guidelines
Colorado Department of Agriculture
1-2018 Colorado MP3 - Guidelines.pdf

Introduction to Integrated Pest Management
US Environmental Protection Agency
www.epa.gov/ipm/introduction-integrated-pest-management

BeeCheck
Apiary Registry by FieldWatch
co.beecheck.org/about

Guidance to Protect Habitat from Pesticide Contamination: Creating and Maintaining Healthy Pollinator Habitat
Xerces Society for Invertebrate Conservation
xerces.org/publications/fact-sheets/guidance-to-protect-habitat-from-pesticide-contamination

Pesticide Drift
Pesticide Environmental Stewardship
pesticidestewardship.org/drift/Pages/default.aspx/

UC IPM Bee Precaution Pesticide Ratings tool
University of California, Davis
www2.ipm.ucanr.edu/beeprecaution/

Fungicide Impacts on Pollinators
Xerces Society for Invertebrate Conservation
xerces.org/publications/fact-sheets/protecting-pollinators-from-pesticides-fungicide-impacts-on-pollinators

Impacts of Pesticides on Invertebrates Database
www.pesticideimpacts.org/

Ecologically Sound Mosquito Management in Wetlands
Xerces Society for Invertebrate Conservation
xerces.org/publications/scientific-reports/ecologically-sound-mosquito-management-in-wetlands

3.2.6. Integrated Weed Management & Herbicides

Integrated Weed Management

Invasive species are currently one of the largest drivers of environmental change worldwide, altering biodiversity and ecosystem functioning by displacing native species, dominating communities, spreading widely, and reducing the diversity of natural communities significantly. Invasive plants dominate millions of acres of forests, grasslands, wetlands, and deserts, and in addition to their degradation of natural areas, also incur economic impacts on agriculture, forestry, and other US industries (Anderson et al. 1996; Pimentel et al. 2005). Invasive plants can cause significant harm to pollinators by reducing habitat quality and disrupting plant–pollinator mutualistic relationships (Brown and Paxton 2009; Potts et al. 2010). Many plant invasions can be prevented, slowed, or reversed, with a return to healthy native ecosystems through management. Pollinator communities respond positively to invasive plant removal, with bee and butterfly communities rebounding in the years following invasive weed control (McKinney and Goodell 2010; Hanula and Horn 2011; Fiedler et al. 2012).

A key strategy for the control of invasive species in natural areas and other areas with pollinator habitat is to take steps to prevent the spread and further establishment of invasive weeds. Preventative actions include minimizing soil disturbance, methods to limit the introduction of weed seeds (e.g., cleaning of equipment or signage on trails), identification and monitoring to detect and respond to new outbreaks, adaptive management to integrate new findings and reevaluate management plans as needed, and using a range of control methods within an integrated approach. The biology of the weed involved, along with site features, worker and public safety, and sensitive species on site can all help inform weed-management approaches. Each method has advantages as well as disadvantages:

- **Mechanical removal**, such as pulling, cutting, or otherwise removing or damaging plants can be effective for targeted weed control, but may be labor intensive with repeated treatments needed, more suited to small weed populations, or causing disturbance via equipment (e.g., mowing). Mechanical techniques can be used in combination with other techniques (e.g., herbicide application following a cutting).
- **Grazing by livestock** can be particularly effective for larger weed infestations, though the species of grazer, along with the duration and timing of grazing, must be carefully considered, so that sites are not overgrazed or have significant soil disturbance. Additionally, use care when moving livestock that have grazed infested areas, as livestock can move invasive weed seed in their coats or pass them through into feces if grazing invasive species after seed set.
- **Prescribed fire** can knock back some invasive species, in particular woody species that spread into unburned grasslands or forests, but requires training and certification to implement and may not be appropriate for many landscapes.

Figure 3.20. Goat grazing on weeds and being used for weed management. (Photo: US Fish and Wildlife Service.)

- **Classical biological control**, the introduction of a non-native species that, within its native range, feeds upon the target non-native invasive weed, can provide long-lasting and widespread control. However, before biological control agents are released, much research should be devoted to understanding the potential impacts to nontarget native species, because introductions can result in irreversible harm to nontarget species. An example of such a situation is the *damage to wavyleaf thistle (Cirsium undulatum*) by the non-native weevil *Larinus planus* that was released in Colorado for biological control of Canada thistle (*C. arvense*) (Louda and O'Brien 2002).
- **Chemical control**, applying a herbicide to an invasive plant, is another tool for weed management. Herbicides can avoid ground disturbance, can be highly effective in killing target weeds, can reduce the risk of injury to workers, and can also be used economically in combination with non-chemical methods. However, herbicides can have environmental risks, with impacts on terrestrial and aquatic nontarget species, and also require training to apply.

There are many factors to balance when developing management plans to control invasive species. We focus here in detail on herbicide applications because herbicides are such a widely used tool by state agencies and because certain uses have the potential for significant impacts to pollinators.

Herbicides

Herbicides are used to control noxious and invasive weed species, as well as woody vegetation and other undesirable plant species, in natural areas and within built environments. Controlling noxious and invasive weeds is critical for maintaining pollinator habitat, particularly habitat for imperiled species (Schultz and Dlugosch 1999). Invasive plants impact pollinators in numerous ways, including by outcompeting their food sources, altering the structure of pollinator habitat, and even changing pollinator behavior (Severns 2008). Using herbicides to suppress noxious and invasive weeds and other undesirable vegetation can support pollinators indirectly by encouraging the valuable native plants that provide pollinators with food or shelter. As an example, grass-specific herbicides can be an important tool in controlling the invasive grasses that threaten Kincaid's lupine (*Lupinus oreganus*), the key host plant for the federally endangered Fender's blue butterfly (*Icaricia icarioides fenderi*) in Oregon (Schultz and Ferguson 2019). However, when used extensively, herbicides can significantly reduce the quality of pollinator habitat (Kremen et al. 2002; Tscharntke et al. 2005; Crone et al. 2009) and some may also be toxic to certain pollinators (Russell and Schultz 2010; LaBar and Schultz 2012).

Herbicide use that reduces or eliminates caterpillar host plants or the flowers that provide pollen and nectar can have adverse impacts on pollinators, particularly imperiled pollinators that might have specific habitat

Some problematic weeds provide resources for pollinators (Harmon-Threatt and Kremen 2015). However, nonnative plants typically support only a subset of the overall pollinator community (Tallamy and Shropshire 2009). In addition, noxious weeds reduce overall plant diversity, which also reduces pollinator diversity (Memmott and Wasser 2002; Zuefle et al. 2008). When noxious and invasive weeds are removed and plant diversity recovers, pollinator abundance and diversity rebounds as well (Hanula and Horn 2011; Fiedler et al. 2012). The value gained by pollinators from keeping an invasive weed is much smaller than the risks posed by retaining that species in the landscape; use by pollinators should not preclude removal.

Figure 3.21. Utility Terrain Vehicle with herbicide spray tank and hose reel for targeted weed treatments in Route County, Colorado. (Photo: Todd Hagenbuch.)

needs (Kearns et al. 1998; Belsky and Joshi 2020). Large-scale or overuse of herbicides can weaken stands of vegetation and associated mycorrhizal fungi, making them more vulnerable to weed invasions (Druille et al. 2016). Off-site movement (e.g., drift, volatilization, and subsurface movement) of some herbicides can also cause reduced floral abundance, delay the onset of flowering, and reduce pollinator visitation (Boutin et al. 2014; Bohnenblust et al. 2016). Pollinators can be sensitive to these subtle changes in the timing and quality of floral resources. Doses of herbicides at the levels found in off-site drift can also reduce pollen germination and seed production for flowering plants, thereby reducing reproduction and replenishment of the seed bank for pollinator-supporting species (Gove et al. 2007; Boutin et al. 2014).

Pollinators may be exposed to herbicides through direct contact, contact with herbicide residuals on flowers or nesting materials, or ingestion (e.g., caterpillar consumption of treated host plant; bee consumption of contaminated nectar). Although herbicides are designed to kill plants and their mode of action is not intended to harm insects, research has found that some herbicides can cause direct harm to pollinators. For example, studies indicate that butterflies exposed to certain herbicides experience sublethal effects such as reduced body size or wing size, which can reduce survival (Russell and Schultz 2010; Stark et al. 2012; Bohnenblust et al. 2013; Schultz et al. 2016). Alterations in development induced by herbicides can have population-level impacts (Russell and Schultz 2010), and herbicide exposure that reduces caterpillar or pupal survivorship can reduce populations over time (Stark et al. 2012). Honey bees exposed to certain herbicides experience altered behaviors such as impaired learning and navigation (Balbuena et al. 2015; Mengoni Goñalons and Farina 2018), or physiological responses including reduced growth or delayed development (Dai et al. 2018; Vazquez et al. 2018).

There are a number of unknowns about the potential toxicity of herbicides to pollinators. What is known about how pollinators respond to herbicide exposure is based primarily on the standard laboratory toxicity testing of adult honey bees required by the US Environmental Protection Agency (EPA) in advance of pesticide registration in the United States. These tests look at acute toxicity to contact with the active ingredient of an herbicide and measure the time it takes for a dose to kill half of the test population of honey bees, a measure known as the LD50; the smaller the dose it takes to kill half of the test bees, the higher the toxicity. However, there are sublethal effects caused by herbicides that are not captured by these screenings, but are impactful to pollinator health. There is also very little information available on herbicide toxicity to larval bees, wild bees, or adult or larval butterflies and other pollinators. How one species of butterfly or pollinator responds to an herbicide may not predict the response of another; the toxicity of herbicides to different butterfly species can vary (Brown 1987; Kutlesa and Caveney 2001; LaBar and Schultz 2012).

Additionally, the effects of tank mixes of herbicides on pollinators and insectivorous animals further up the food chain are largely unknown. The effects of inert ingredients in formulated products on pollinators are also generally unknown, but there are indications that ingredients like surfactants can sometimes be more toxic to pollinators than the active ingredient alone (Mesnage and Antoniou 2018; Straw et al. 2021). Because the EPA only requires standard laboratory tests that assess the acute toxicity of the active ingredient, not the formulated product that is actually applied in the field, the real-world impacts of herbicide exposures are understudied.

Practices to reduce the impacts of herbicides to pollinators include:

- Using herbicides within a vegetation management plan that employs multiple strategies,
- Preventing weed outbreaks,
- Using products selectively,
- Timing applications carefully,
- Reducing off-site movement,
- Reducing direct herbicide exposure to pollinators, and
- Providing education and communication of expectations for applicators.

These practices are appropriate to consider for all the different types of landscapes that the state must consider from roadsides, parks and natural areas, and working lands to landscaped environments.

Recommendations for Herbicide Use That Apply to All Landscapes

Use Herbicides Within an Integrated Weed Management Approach

Use herbicides within an integrated vegetation management plan. Evaluate the range of management techniques (e.g., chemical, cultural, biological, and mechanical) in order to select the most effective, feasible, and least-harmful weed management method(s) that can increase or conserve the abundance and diversity of blooming plants at the site. Different sites will have different management plans because of their unique attributes (e.g., mechanical removal might be appropriate for a small site with easy access). Use herbicides only when less-damaging methods are not available or feasible.

Always apply herbicides according to label directions. Use the minimum application rate that will effectively control the weed. Prioritize the use of formulations that are jointly terrestrial- and aquatic-approved, and that have lower residual activity and shorter half-life, when possible, in order to minimize potential impacts on the environment following applications.

Keep records of locations where herbicides are applied. Records of the plants treated, application method, type and the amount of herbicides used, and dates of application can help to evaluate the effectiveness of treatments over time and can be useful when adjusting management decisions. Multiple seasons of herbicide applications or other weed control methods may be needed to fully control an invasive species.

After treatment, monitor resulting conditions and outcomes, and adapt management plans. Monitoring will help to evaluate the effectiveness of management practices on target plants and any effects on nontarget plants. If desired conditions were not produced or if site conditions change, adapt management practices accordingly.

Prevent Conditions That Would Allow Incompatible Vegetation or Noxious & Invasive Species to Establish or Reestablish

Clean spray equipment between applications of different products, if needed. Follow label directions and standard practices when rinsing or cleaning spray equipment between work sessions; incomplete removal of a prior herbicide mix can have detrimental impacts to the next treatment area.

Clean application equipment between sites. After equipment is driven through areas of weed infestations, avoid spreading weed seeds between sites by spraying the vehicle's tires and undercarriage with an air compressor to remove weed seeds and prevent their unintentional spread.

Treat flowering undesirable species before they bloom. Applying herbicides to flowering weeds before they bloom and set seed will reduce the weed seed bank, the reservoir of weed seeds in the soil. Many noxious and invasive weeds have pervasive seed banks, with seeds that can survive many years before germination. If weeds are treated during bloom or after seed set, their populations may persist in future years. Similarly, control woody plants that resprout or sucker to stop regrowth.

Reseed areas with desirable species following treatments as needed. After treating a dense infestation, consider seeding or replanting the area, if necessary (e.g., if the seed bank was depleted of desirable species). Plant with desirable, competitive native species suitable for the location to reduce the potential for weed species to reestablish. Always make sure that seed and vegetative planting stock is free of weed species. Revegetation with appropriate native plants can support pollinators while also helping to reduce weed pressure and need for continued weed management.

Avoid large-scale application of herbicides when the persistence of existing native vegetation or the recruitment and establishment of native species from the seedbank is desired. Preemergent herbicides can significantly suppress the emergence and biomass of native species (Wagner and Nelson 2014). Persistent herbicides applied broadly can also suppress native vegetation (Skurski et al. 2013).

Monitor vegetation regularly to stay on top of emerging weed outbreaks. Early detection of weeds can result in improved control and may reduce the amount of herbicide needed overall. Document desirable plants that may be present, such as native nectar plants and host plants, including milkweeds.

Limit Nonselective Broadcast Applications and Use Targeted Approaches

Prioritize the use of selective herbicides to reduce damage to nontarget plants. Whenever possible, the use of selective herbicides—those formulated to control specific weeds or groups of weeds—can reduce damage to nontarget plants.

Use care with the timing of applications and methods. To avoid weakening desirable plants it is important to apply herbicides, especially nonselective herbicides—those that are broad-spectrum products and kill or damage all plants—selectively, i.e., in a targeted manner and at the appropriate time to interrupt the weed's life cycle. For example, applications can be made when desirable native plants are dormant and through spot spraying or other targeted application methods).

Use targeted herbicide applications to avoid harming nontarget species. To avoid weakening or affecting flowering and seed set among desirable species, weeds can be targeted using spot treatment applications made with a backpack sprayer, weed wiper, or similarly appropriate technology. Using highly targeted applications on cut stems, on stumps, or under bark can also reduce unnecessary effects on desirable plants. Use broadcast treatments or pellet dispersal only for dense infestations of weeds.

Consider spray dyes to indicate areas that have been treated. Use an approved marker dye with spot treatments or cut stem and stump treatments to allow the applicator to know the target has already been treated and the extent of target coverage. Spray dyes reduce likelihood of an accidental retreatment or missing treatment of a target weed.

Avoid the use of preemergent herbicides on areas where the seed bank might contain desirable native species. Native plant species can be beneficial to pollinators and other wildlife; therefore, choose other methods of weed suppression in areas with desirable species.

Apply Herbicides to Maximize Their Efficacy

Applying herbicides in ways that augment their efficacy can ultimately reduce the amount applied. Applications can be timed to be most effective, based on the herbicide's mode of action, the application technique, and the target plant species.

Apply herbicides during plant life stages when weeds are most vulnerable. For example, when using a systemic herbicide (i.e., absorbed by the plant and transported throughout the plant by the vascular system), perennial weeds can be treated in late-summer and fall. During this period, perennials begin to move sugars down to their roots; the herbicide is translocated to vegetative reproductive structures where it is most effective at controlling the plant. Applications of herbicides when the weed is most vulnerable are the most successful applications. For many weeds, this is the seedling or rosette stage.

Coordinate spray operations with mowing or other weed-management strategies to enhance weed control. For example, it may improve control to treat mature weeds when they are actively growing, shortly after mowing.

Reduce Off-Site Movement of Herbicides

Apply herbicide sprays when weather conditions will minimize drift. It is best to avoid applications when wind speeds are greater than 10 mph (16 kph) or during temperature inversions. During inversions, when warmer air above traps cooler air near the ground, herbicides and other pesticides can linger in the air and travel long distances off-site with air movement. Calm conditions with no wind, or wind speed below 2 mph (3 kph), can suggest a possible inversion. Reducing the off-site movement of herbicides and using nonselective broadcast applications can help avoid exposure to pollinators and damage to the nontarget plants that provide pollinators with food or shelter.

Choose and calibrate equipment with drift management in mind. The off-site movement of herbicides can be reduced by selecting appropriate spray equipment, calibrating equipment according to manufacturer specifications at least on an annual basis, and adhering to instructions on the pesticide label. Nozzles that produce larger droplets are less likely to cause herbicides to drift off target. Equipment that is calibrated regularly limits over and under applications. On boom sprayers, use the lowest effective pressure and largest droplet size possible.

Select herbicides with low volatility, when feasible, to reduce the off-target movement of herbicide vapors. Do not apply herbicides when temperatures are high (see product label for more information) or during temperature inversions, when herbicides are more likely to volatilize.

Consider the use of drift reduction equipment or agents, if appropriate. Some spray equipment can be modified with sprayer shields that block particle drift. Drift-reduction agents can also be added to sprays to reduce small droplets and drift.

Avoid large-scale use of adjuvants when possible. Some adjuvants—products added to a spray solution to enhance performance of post-emergence herbicides—have known toxicity to bees or may have other nontarget impacts that are not well studied (Ciarlo et al. 2012; Mullin 2015). Adjuvant classes with known toxicity to pollinators include organosilicone and alcohol ethoxylate surfactants (Mullin et al. 2016; Straw and Brown 2021; Wernecke et al. 2022). If using adjuvants, select those that are terrestrial- and aquatic-approved, and compatible with the selected herbicide formulation.

Limit Exposure of Pollinators to Herbicides

Avoid herbicide applications to flowering plants during bloom. Treatment of weeds during their vegetative phase reduces the exposure of adult pollinators foraging on flowers to herbicides and adjuvants. Pollinators foraging on flowers after herbicides are applied can be exposed to systemic herbicides in nectar and pollen before treated plants show signs of herbicide injury (Thompson et al. 2022).

Avoid broadcast applications of systemic herbicides and persistent herbicides with long residual periods to reduce the exposure to butterfly and moth caterpillars. Butterfly and moth caterpillars, which consume host plant vegetation over days to weeks, can be exposed to herbicides by consuming contaminated vegetation. Residues in host plants could account for the bulk of exposure over the life cycle of these species. Larval butterflies and moths could be chronically exposed to systemic herbicides that are taken up by host plants or the residues of persistent herbicides, which take weeks to dissipate in the environment and have detrimental sublethal effects (Olaya-Arenas et al. 2020).

Avoid the use of products that have toxicity to imperiled species during breeding seasons. Time the use of fluazifop-p-butyl and sethoxydim, which may have sublethal effects on imperiled skipper or nymphalid butterflies, after caterpillar activity (e.g., make applications in late-summer or early fall). In an area where herbicide use might affect imperiled species, if treatment cannot be scheduled outside the window when pollinators are present, consider a mechanical control strategy.

Avoid direct applications to or near host plants of imperiled species or key sources of pollen and nectar. Host plants and key nectar or pollen plants should not be treated with herbicides or subject to drift from herbicides.

Support Applicators Through Educational Opportunities & Communication of Expectations

Train applicators, whether staff or contractors, in herbicide application techniques that reduce damage to nontarget species. Applicators should have regular ongoing educational opportunities to stay up to date on the latest guidance for weed management, equipment calibration, and herbicide techniques for efficacy and targeted applications. This includes unlicensed technicians along with licensed private and commercial applicators, limited commercial applicators, and public applicators.

Train applicators to distinguish undesirable vegetation from nontarget plants. Conducting training in identification of noxious and invasive weeds or encroaching woody vegetation, as well as using plant identification reference materials to recognize key native plant species, will help to reduce unintended damage to nontarget plants. For instance, training may help crews to distinguish the invasive introduced Canada thistle (*Cirsium arvense*) from the native wavyleaf thistle (*C. undulatum*) or Flodman's thistle (*C. flodmanii*), important native nectar plants for bumble bees and butterflies. Ensure that trained staff are on site to identify vegetation during management activities.

If imperiled pollinator species are present, train applicators to recognize and avoid herbicide applications to important plants. Imperiled pollinators often have specific plants that they rely on for survival, such as larval host plants for butterflies and moths, or key nectar plants for bumble bees. Recognition of the plants that are important to imperiled pollinators by applicators is a strategy that can help reduce applications to nontarget plants. Profiles of imperiled pollinators with information about their host plant needs are found in Appendix IV of this report. Use available maps to determine where imperiled pollinator species and their host plants may be located.

Create specifications for contractors that include techniques to reduce impacts to pollinators. Include specifications about recommended techniques applicators should use to minimize impacts to pollinators (e.g., application methods, time, product selection) in contracts, to ensure that contractors are using herbicides as effectively and carefully as possible in accordance with label directions.

> "Staff turnover is hard to keep the maintenance crews educated on vegetation management when education needs to be for safety critical roadway/roadside elements."
>
> - Colorado Native Pollinating Insects Health Study Agency Survey Participant

Additional Resources

Native Plant Revegetation Guide for Colorado
Colorado Natural Areas Program, Department of Natural Resources
cpw.state.co.us/documents/cnap/revegetationguide.pdf

Roadside Habitat for Monarchs: Monarch Butterflies, Weeds, and Herbicides
Xerces Society and Monarch Joint Venture
xerces.org/publications/fact-sheets/roadside-habitat-for-monarchs-monarch-butterflies-weeds-and-herbicides

Preventing the Spread of Invasive Plants: Best Management Practices for Transportation and Utility Corridors
California Invasive Plant Council
www.cal-ipc.org/resources/library/publications/tuc/

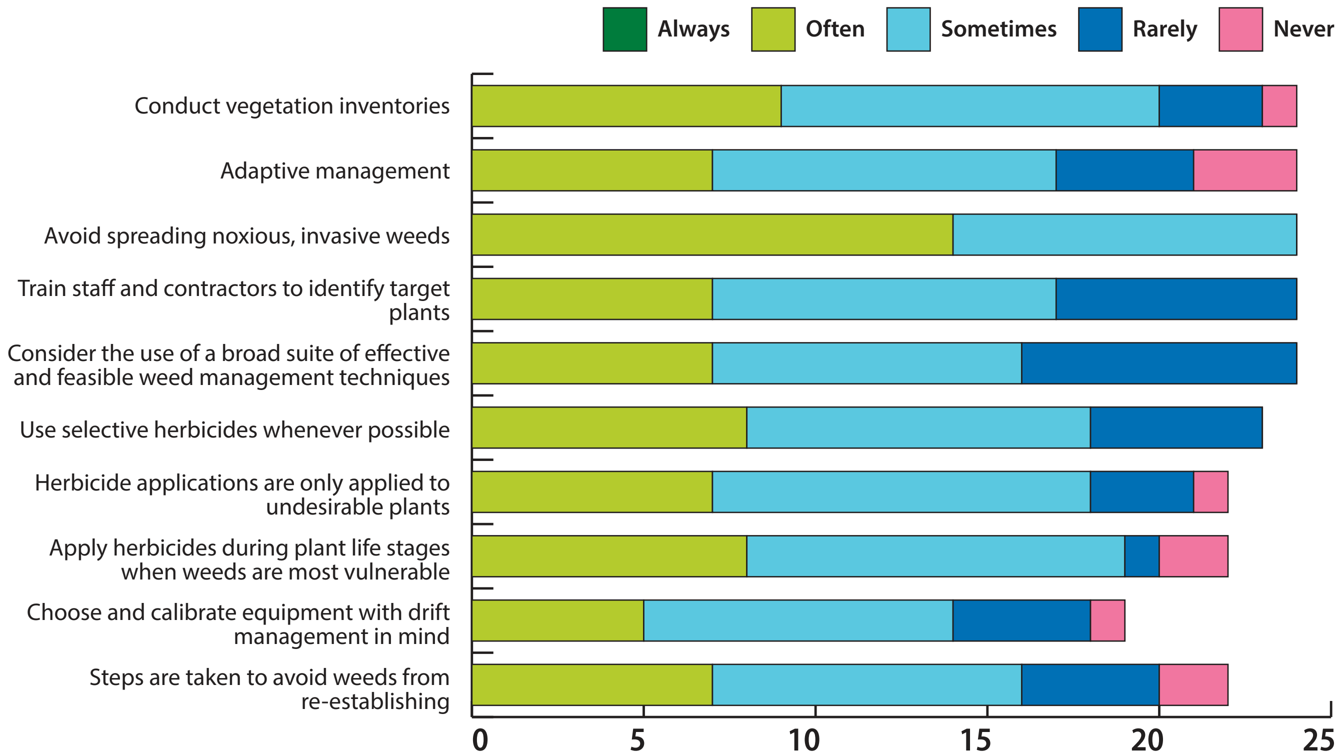
Best Management Practices for Wildland Stewardship: Protecting Wildlife When Using Herbicides for Invasive Plant Management
California Invasive Plant Council
www.cal-ipc.org/resources/library/publications/herbicidesandwildlife/

State Pollinator Conservation Herbicide Practices

The survey of state staff included a series of questions about weed-management practices related to the use of herbicides. Most (89%) of the respondents indicated their agency did use herbicides, and the frequency of use was fairly common (sometimes, 40%; often, 32%; always, 8%). Staff were also asked about the frequency of use of specific weed and herbicide management practices that mitigate impacts to pollinators (see Figure 3.22 on next page). Taking steps to avoid the spread of noxious and invasive weeds is clearly the most-frequent practice. Other more-common practices include conducting vegetation inventories, using selective herbicides whenever possible, targeting only undesirable plants, and applying herbicides when the weeds are most vulnerable. The least-common practices are adaptive management, training applicators to identify target plants, using a broad suite of techniques, calibrating equipment with drift in mind, and taking steps to avoid weeds reestablishing. These practices had higher rates of "never" or "rarely" being used. The less-common practices are good places for weed program managers to target adding these to operational procedures.

Several questions also focused on the feasibility of implementing two key practices, an IPM program and applying selective pesticide/herbicide treatments to specific spots needing treatment. Selective and spot treatments are very feasible to implement (medium, 31%; high, 49%) and implementing an IPM program a little less feasible (medium, 38%; high, 28%). There were more "not applicable" responses (21% compared to 8%) for implementing an IPM program. Some of the contributing factors that could make implementing IPM "not applicable" or less feasible for state agencies that do manage weeds are circumstances where lessees are responsible for weed management, as is the situation for many SLB properties. If this is the case, providing information about and encouraging or possibly requiring the consideration of recommended weed-management and herbicide practices as part of lease terms may be an important way to promote the evaluation of practices that could help protect pollinators.

Figure 3.22: How frequently does your agency currently implement the following weed management practices?



Challenges & Barriers to Implementing Pollinator Conservation Herbicide Practices

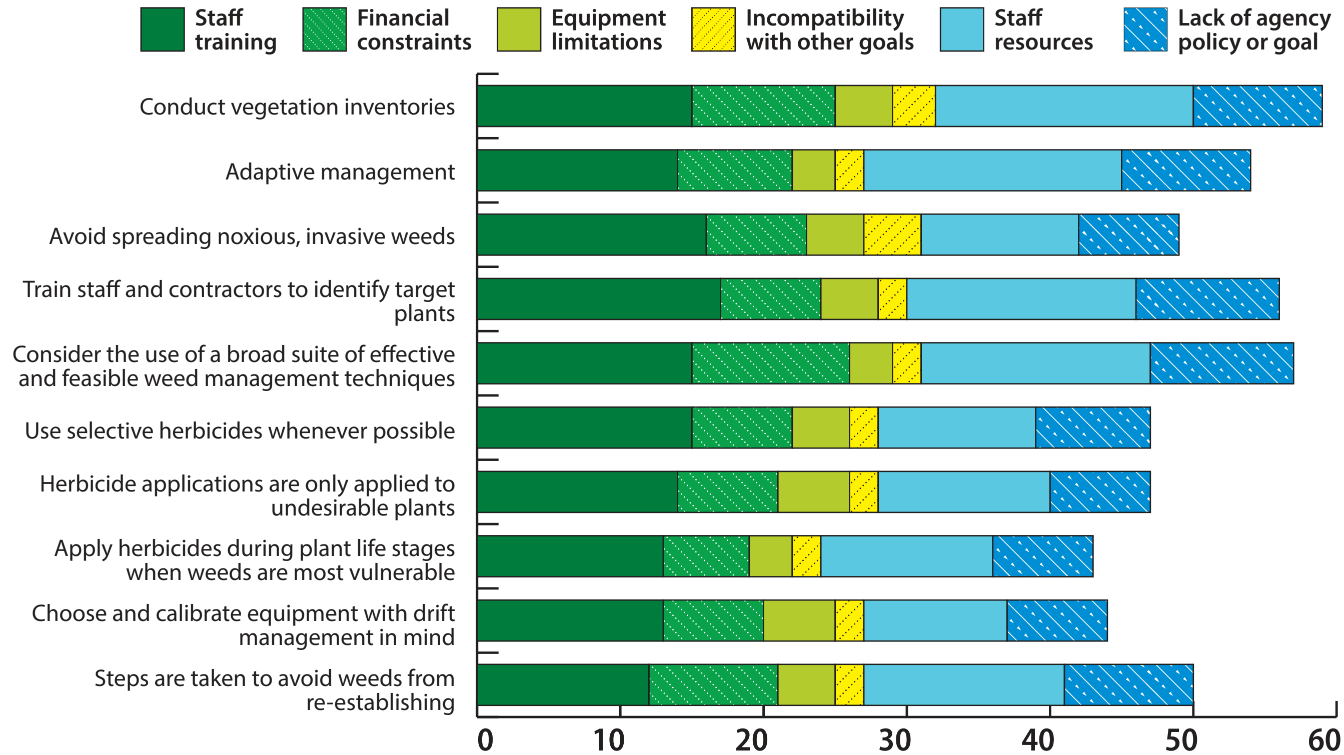
Survey questions focused on common barriers to implementing more pollinator conservation focused herbicide management practices pointed to two barriers as more prominent issues to consider:

- Lack of staffing, and
- Lack of staff training.

Figure 3.23 (next page) contains survey results about potential barriers that limit weed-management and herbicide practices that reduce risks to pollinators. After lack of staffing and staff training, the next most common barriers that create challenges for staff are financial constraints and lack of agency policy or goals. These four barriers are where attention should be paid when determining how to increase the use of practices that benefit pollinators. The survey results also indicate that incompatibility with other goals and equipment limitations are relatively minor barriers, and thus, less important to focus on.

It isn't surprising that keeping staff trained poses a significant barrier for implementing pollinator-oriented herbicide practices since many of the practices require specific knowledge and skill development. Practices such as training to help identify targeted weeds and native plants, selecting the appropriate timing of management and approach for the weed being treated, selecting the appropriate herbicide and application equipment, and calibrating the equipment effectively to prevent drift, are just some of the examples of practices that rely on more thorough training of staff and contractors applying treatments. When contractors are used, creating specifications that align with the practices creates an additional step and complexity. Another complicating factor to ensure staff is adequately trained is that the turnover of staff doing the work may constantly require catch up training for newly hired staff.

Figure 3.23: What are the barriers for your agency to implement the following weed management practices?



With the lack of training being a common barrier to effective implementation of practices, the survey asked how agencies support weed-management education and training. Keeping up to date on the latest techniques and emerging weed issues through collaborations with other agencies or organizations is the primary way that state staff stay informed. Two thirds of the respondents also indicated that their agencies support continuing education opportunities, acquiring certifications, and have weed-management and herbicide specifications. Agency-provided training for staff was a little less common, with 58% of the respondents indicating this occurs. If one of the constraints to doing more agency-based training is having adequate expertise, expanding the capacity and expertise for conducting training, tapping into the expertise within other state agencies, and making use of partner organizations like the CSU Extension could be ways to make sure there is available expertise. Staff interviews pointed out that CDOT will begin specific in-house training in 2024, an effort that should be strongly endorsed.

As has been discussed in previous pollinator-conservation practice sections of this report, the lack of training often corresponds with a lack of agency policy and goals that can assist in emphasizing the importance of prioritizing training. Assessing current policy directives, seeking input from staff to identify gaps or additions needed to support training priorities, and making sure there is a way to ensure training occurs could be helpful steps to increase training efforts.

Lack of staffing and funding resources were also raised as limiting factors. This is likely due to the need for funds and staffing necessary for having effective training programs, capacity to manage an integrative program, and ensuring staff have the time, skills, and flexibility to apply recommended conservation practices. The funding barrier is a difficult challenge to address, but critical to the effective implementation of weed management practices that will result in desired outcomes that also help pollinators thrive.

3.2.7. Restoring Existing Pollinator Habitat & Creating New Pollinator Habitat

Habitat degradation and loss of habitat are major factors contributing to pollinator declines (Kearns et al. 1998; Goulsen et al. 2008; Grixti et al. 2009; Winfree et al. 2009). In Colorado, commercial, residential, and energy development have been primary drivers of land conversion within the last two decades (Theobold et al. 2016). It is critical to preserve remaining native habitats, and prevent the conversion and degradation of existing natural areas on private and public lands. Restoration of existing habitat and the creation of new habitat are important strategies to ameliorate habitat loss and conserve native pollinators (Tonietto and Larkin 2017; Denning and Foster 2018; Glenny et al. 2022). The removal of noxious and invasive plant species in natural areas increases bee abundance and diversity (Hanula and Horn 2011; Fiedler et al. 2012), and restoration projects with plant community goals also frequently have ancillary benefits for bees and other pollinators (Tonietto and Larkin 2017). Creating new pollinator habitat, whether through revegetation of roadsides (Ries et al. 2001; Hopwood et al. 2015; Philips et al. 2020), utility corridors or resource extraction corridors (Wojcik and Buchmann 2012; Curran et al. 2019), habitat plantings on farms to support agricultural biodiversity (Kremen et al. 2007; Blaauw and Isaacs 2014; Albrecht et al. 2020), or landscaped plantings in parks, cities, and gardens (Matteson et al. 2008; Frankie et al. 2009; Banaszak-Cibicka and Żmihorski 2012; Wray & Elle 2014; Hall et al. 2017; Majewska et al. 2018).

Restoring existing habitat and creating new pollinator habitat is crucial for improving climate resilience of pollinator communities. Habitat with abundant pollinator-attractive floral resources that bloom from spring through fall is required to support large, stable, and diverse pollinator communities, and larger populations of pollinators, in general, will better withstand extreme weather events that become more frequent with climate change. Diverse habitat can also include spaces where pollinators can survive extreme weather, niches of habitat that can ultimately help to buffer pollinators from extreme weather events. Habitat connectivity can also help habitat and pollinators be more resilient. Corridors and habitat "stepping stones" allow pollinators to move throughout landscapes, increasing gene flow, enabling migrations, and facilitating range shifts in response to climate change. While not all species will change distributions in response to climate change, increasing habitat connectivity provides the opportunity for those that will.

Understanding the habitat requirements of pollinators can help planners identify specific pollinator habitat goals for restoration or habitat creation plans. For example, protecting or providing nest sites is as important as providing flowers to support populations of native bees (Tscharntke et al. 1998; Cane 2001; Potts et al. 2005). Similarly, caterpillar host plants are necessary for robust butterfly populations (Feber et al. 1996). Ideal habitat for pollinators would have overwintering or nesting sites, host plants, and forage resources in the same habitat patch. Pollinators are able to adapt to landscapes in which overwintering and nesting are separated from forage resources, but it is important that these two key habitat components are not too far apart (Westrich 1996; Cane 2001). Table 3.2 provides an overview of habitat needs of pollinators and how revegetation projects can meet those needs. Even if pollinators are not the primary objective of a restoration or revegetation project, elements that increase the value of the revegetation project to pollinators can be incorporated into project objectives. To meet objectives such as water-quality protection and erosion control, quick-growing native wildflowers and grasses can be used, including species that also provide resources for pollinators. Deep-rooted shrubs or trees might be used for visual enhancement, stabilization, snow retention, or carbon sequestration; selecting species that provide larval food or pollen and nectar will also enhance the project's value to pollinators. Consideration of the needs of pollinators when planning a revegetation project can have significant benefits for pollinators.

Native plant communities are the foundation of healthy pollinator habitat. Habitat with native wildflowers support a greater number of individuals and species of butterflies and bees. Native plants are often more attractive as sources of pollen and nectar for adult pollinators than non-native plants and support more species and more individuals, even when both plant types are present on the same site (Williams et al. 2011; Morandin and Kremen 2013). Native plants also support more caterpillars than do non-native plants (Narango et al. 2017). Studies in the eastern United States showed that native woody plants support fifteen times more native butterflies and moths than do introduced species of ornamental plants (Tallamy and Shropshire 2009). Adding non-native plants to landscapes does not increase butterfly and moth diversity or abundance (Burghardt et al. 2010), and non-native plants can reduce bird populations as a consequence of reduced insect availability (Narango et al. 2018). Beyond bees and butterflies, native plants also best support beneficial insects that provide natural pest control (Isaacs et al. 2009). Use of native plants in new plantings confer other benefits: native plants are well adapted to local growing conditions, require minimal inputs for establishment, are able to better tolerate extreme weather, have root systems that can increase water infiltration to replenish groundwater and reduce erosion, and can resist weed invasions—and showcase a region's natural beauty and heritage (Cramer 1991; Bugg et al. 1997; Quales 2003; Blumenthal et al. 2005; Falk et al. 2013; Harrison 2014).

Figure 3.24. Wildflowers bloom in this native plant restoration adjacent to the Lunch Loops Trailhead in Mesa County, Colorado. (Photo: Kenton Seth.

Table 3.2. Restoration Goals for Creating or Enhancing Habitat for Pollinators

TAXA	FOOD	SHELTER, OVERWINTERING	GENERAL RESTORATION GOALS
Bumble bees	• **Larval:** Provisions of nectar and pollen within the nest. • **Adult:** Nectar and pollen.	• Nest in small underground cavities in abandoned rodent nests, under clumps of grass, or in hollow trees, bird nests, or walls. • Queens overwinter in soil and under leaf litter and other debris.	• Increase density and diversity of native flowering plants. • Include species with sequential bloom periods; early season blooms are particularly important. • Plant native bunch grasses for bumble bee nesting habitat.
Ground-nesting bees	• **Larval:** Provisions of nectar and pollen within the nest. • **Adult:** Nectar and pollen.	• Excavate nest tunnels in bare or partially vegetated, well-drained soil. Developing bees remain in the nest through winter.	• Increase density and diversity of native flowering plants. • Retain areas with bare or partially vegetated, well-drained soil.
Tunnel-nesting bees	• **Larval:** Provisions of nectar and pollen within the nest. • **Adult:** Nectar and pollen.	• Nest in narrow tunnels in dead standing trees, or excavate nests in hollow stems or pith of twigs. Some construct domed nests of mud, plant resins, saps, or gums on the surface of rocks or trees. Developing bees remain in the nest through winter.	• Increase density and diversity of native flowering plants. • Retain or install woody plants and herbaceous plants with hollow or pithy stems. • Leave snags where they create no safety hazard.
Beetles	• **Larval:** Some species are herbivorous, feeding on plants; many are carnivorous and eat prey such as aphids, slugs, and insect eggs. • **Adult:** Pollen, nectar, floral parts; some species are also carnivorous.	• Overwinter in soil or leaf litter, under rocks, logs, brush, or bark.	• Increase density and diversity of native flowering plants. • Maintain vegetation structure. • Retain overwintering sites when feasible.
Butterflies	• **Larval:** Vegetation of host plants. • **Adult:** Nectar; some males obtain nutrients, minerals, and salt from rotting fruit, tree sap, animal dung and urine, carrion, clay deposits, and mud puddles.	• Protected sites such as a tree, bush, tall grass, or a pile of leaves, sticks, or rocks. (Will also shelter in buildings or other structures.)	• Increase density and diversity of native flowering plants. • Include specific host plants. • Maintain vegetation structure.
Flower-visiting moths	• **Larval:** Vegetation of host plants. • **Adult:** Nectar; some gather sugary fluids from rotting fruit or tree sap.	• Protected sites such as a tree, bush, tall grass, or a pile of leaves, sticks, or rocks.	• Increase density and diversity of native flowering plants. • Include specific host plants. • Maintain vegetation structure.

TAXA	FOOD	SHELTER, OVERWINTERING	GENERAL RESTORATION GOALS
Flies	• **Larval:** Some species are carnivorous, consuming prey such as aphids, scales, or mites; others are decomposers in the soil. • **Adult:** Nectar; some species also eat pollen.	• Overwinter in soil or leaf litter.	• Increase density and diversity of native flowering plants. • Maintain vegetation structure. • Retain overwintering sites when feasible.
Wasps	• **Larval:** Provisions of insect prey such as caterpillars, aphids, grasshoppers, planthoppers, true bugs, and more. • **Adult:** Nectar.	• Similar nesting needs as bees, with solitary species nesting in the ground or tunnel nests in wood or cavities in mud or resin. Developing wasps remain in the nest through winter. • Social species build nests with wood pulp. Queens will overwinter in sheltered locations.	• Increase density and diversity of native flowering plants. • Retain areas with partially vegetated well-drained soil. • Retain or install woody plants and herbaceous plants with hollow or pithy stems.

This table was adapted from Hopwood et al. 2015

Restoring Existing Pollinator Habitat

Existing habitat that supports pollinators, such as natural areas, rangelands, field borders on farms, roadsides, or margins in parks, often requires some level of ongoing vegetation management or disturbance in order to maintain plant diversity, and thus, habitat for pollinators. The effects of plant succession, overly competitive native species, the invasion of non-native weeds, or vigorous management can degrade plant communities. Applying management techniques can move a degraded ecosystem toward recovery, bringing back diversity and ecosystem functionality, including plant–pollinator interactions.

Recommendations for Restoring Existing Pollinator Habitat That Apply to All Landscapes

Manage existing habitat to increase native plant abundance and diversity, and to support pollinators. Natural lands can sometimes become degraded due to a large disturbance (e.g., wildfire) or over time due to ongoing intensive management (e.g., overgrazing). Plant diversity can be lost above ground, but below ground the soil seed bank can be robust. Altering management can release the soil seed bank and return a diversity of native plants to the site. For example, a carefully timed grazing event could suppress key weeds, or haying could reduce dominant grasses. For pollinator-specific land management guidance, please see the conservation recommendations for mowing and haying (Section 3.2.2), forestry and trees (Section 3.2.3), grazing (Section 3.2.4), integrated pest management and pesticides (Section 3.2.5), weed management and herbicides (Section 3.2.6), and prescribed fire (Section 3.2.8). In built environments, roadsides often have existing native plant seed banks and many greenspaces may have small areas with native plant seed banks (e.g., creek banks, margins of trails or sports fields fencerows). Altering maintenance pressure (e.g., reducing routine mowing) in these areas can help native vegetation bloom and flourish over time.

At sites where the seed bank is depleted, plant key native species. Interseeding (also known as overseeding), a strategy to sow seeds into established vegetation, can increase flowering plants in existing stands of low-diversity vegetation. Transplants can also be used to increase plant diversity (interplanting). Irrespective of method, it is important to use appropriate vegetation management techniques that can temporarily suppress the existing dominant vegetation so that the new plants can become established.

Additional Resources

Interseeding Wildflowers to Diversify Grasslands for Pollinators
Xerces Society for Invertebrate Conservation
xerces.org/publications/guidelines/interseeding-wildflowers-to-diversify-grasslands-for-pollinators

Maintaining Diverse Stands of Wildflowers Planted for Pollinators
Xerces Society for Invertebrate Conservation
xerces.org/publications/guidelines/maintaining-diverse-stands-of-wildflowers-planted-pollinators

Creating New Pollinator Habitat

Habitat loss is a leading factor in the decline of many pollinators (NRC 2007), and creating new pollinator habitat in places that have no existing habitat to manage is an effective conservation strategy. There are a number of opportunities to create new habitat in the places we live and work, including habitat plantings on farms; revegetating roadsides or other areas where habitat has been disturbed or removed, such as following resource extraction; and landscaped areas or formal gardens in parks, communities, or near buildings or on campuses.

Recommendations for Creating New Habitat That Apply to All Landscapes

Include Pollinator Habitat Needs During Habitat Design

Prioritize the use of native plants. Native plants support both more species and greater abundance pollinators as host plants, as sources of pollen and nectar, and as nesting materials or plant structures that provide shelter. Native trees, shrubs, grasses, and wildflowers all have different functional roles and benefits and can occupy different niches.

Whenever possible, source local ecotype native plants. When purchasing plant materials, native plants and seed should be procured from local ecotype providers (although see comments below on climate resilience). Local ecotype plant materials are adapted to the local climatic conditions, will generally establish well, will have bloom times in sync with local pollinators, and will help to maintain the genetic integrity of local vegetation. Coordinate with native plant vendors early about their plant material needs to allow them to collect foundation seed or grow out plant materials. For some projects, it may be most appropriate to collect seed on site and amplify it for new plantings.

Figure 3.25. Native plants added to a landscaped park and greenway in Boulder, Colorado. (Photo: Jennifer Hopwood, Xerces Society.)

Prioritize wild-type plant material and use native cultivars with care. Some native cultivars are equally as attractive to foraging pollinators as their wild-type counterparts, but other cultivars have been bred for a particular trait such as showiness and may have little to no pollen and nectar and therefore little value to pollinators. It can be difficult to know which cultivars have value to pollinators; keep this in mind when selecting plants.

Increase flowering plant diversity and abundance. High flowering-plant diversity provides sustained resources throughout the growing season to support robust pollinator populations and communities. Floral abundance is also important; sparse resources will not sustain pollinator populations, whereas high densities of blooms are more attractive and can support higher numbers of pollinators (Herrera 1989). A diverse community of native plants can also effectively resist weed colonization and provide soil stabilization.

Include plant species with overlapping and sequential bloom periods. Providing a diversity of flowering plants throughout the growing season supports pollinator species with multiple generations, as well as those that have a single generation each year and time their emergence and flight period with the bloom of certain plant species. Increasing the diversity of flowering plants in seed mixes and planting plans can help to prevent gaps in bloom. Early and late-season sources of pollen and nectar are important for those species that overwinter as adults.

Include host plants for caterpillars. Providing caterpillar host plants is a well-established way to sustain butterfly and moth populations. Many native plants commonly used in habitat projects serve as butterfly and moth host plants (e.g., little bluestem [*Schizachyrium scoparium*]). However, it is necessary to include specific native host plant species matched to support the particular butterfly or moth species that are adapted to feeding on them, given that some species of butterflies and moths rely on plants of a single species or genus as host plants for their caterpillars. For example, planting milkweeds (*Asclepias* spp.) will contribute to the recovery of the monarch butterfly.

Include plants that provide nectar or pollen for pollinators with specialized diets. Some pollinator species need the floral resources from certain flowering plants to survive. Bees that are pollen specialists rear their young on pollen from a certain species or groups of closely related plants. Bumble bee species have different tongue lengths that allow them to feed preferentially on certain flowers. Adult butterflies are often generalist foragers of nectar, but some species may exhibit preferences for nectar from certain plants. If habitat needs are known for species in the project area, include those key plants that support specialist pollinators.

Incorporate nesting or overwintering habitat needs. Some pollinators have very specific nesting or overwintering habitat needs, such as nesting in stems of particular pithy-stemmed shrubs or hollow-stemmed wildflowers, or within tunnels in trees or old logs. When specific habitat needs are known, include those for imperiled pollinators. In general, including a diversity of types of plants in habitat projects creates vegetation structure that provides shelter and overwintering habitat. Trees and shrubs may not be appropriate for every project; in those situations, including a diversity of grasses (both cool- and warm-season grasses) can increase vegetation structure.

Identify habitat refugia that are protected from pesticides. Pesticides can have negative effects on pollinator health, reproduction, and survival. It is important to prioritize sites for pollinator habitat that are adequately protected from pesticide exposure to prevent harm to pollinators and foster healthy, diverse pollinating insect populations.

Consider the potential connectivity of new habitat. If multiple options for locating habitat exist, prioritize the location that increases connectivity to existing habitat within the landscape. Corridors help pollinator populations to better persist and help support more pollinator species.

Plant the right plant in the right place. Select species adapted for the sunlight and soil conditions present at the site (e.g., use moisture-tolerant species for wet soils). Projects that contain special microclimates or soils may require a unique mix of species. If the planting cannot be site specific, include species adapted to a wide range of growing conditions.

Balance grass and forb density in seed mixes. If installing vegetation via seeding, balance the proportion of grass seeds to wildflower seeds. If grass density is too high, grasses will outcompete wildflowers over time, reducing plant diversity. At minimum, 25 percent of the seed mix should be wildflowers, but a mix that is 50 percent wildflowers results in a considerably more diverse and stable planting (Dickson and Busby 2009). In highly visible areas, consider increasing the wildflower component to create more showy plantings. Avoid the use of non-native grasses that can dominate or reduce diversity in plantings (e.g., smooth brome [*Bromus inermis*]).

Include layers in plantings using transplants, container-grown, or bare-root plants. For example, include an understory of shrubs, wildflowers, grasses, or sedges with tree plantings. Layers help to shade out weeds, reduce moisture loss, provide layers of habitat for wildlife, and reduce maintenance requirements. Design plantings with natural plant communities in mind, including species that will grow well together.

Incorporate future vegetation management needs into the design plan. Develop, in collaboration with maintenance staff, a weed management plan for site preparation in advance of planting, weed control during the establishment period, and anticipated ongoing management. Input from maintenance staff can inform the planting design and help the planting be successful.

Consider resilience to climate change. Colorado's climate is projected to shift to increased average temperatures with longer heat waves, increased variability in precipitation, increases in both flooding and drought, and decreases in snowpack. Plant species or ecotypes that are adapted to hotter and drier conditions, increase plant diversity to cover a wider range of tolerance to extreme weather and to extend flowering phenology, and consider mixing the provenances of plant material selection, so that some may be more adjusted to future climates.

Install Native Plant Materials to Promote Establishment of Pollinator Habitat

Conduct weed control on the site to remove competitive vegetation prior to planting. Preparing the site before planting by removing perennial weeds and undesirable plants will result in higher rates of native plant establishment. High weed pressure at some sites might require more intensive weed control or working for more than one growing season.

When Installing Habitat Via Seeds

Select the method of seeding most appropriate for the site and ensure good seed-to-soil contact. Broadcast seeding is an easy method that is useful for sites that cannot be reached by mechanical equipment. However, for it to be most effective, the seed bed must be smooth and as free of stubble as possible prior to planting, and greater quantities of seed should be used (up to 50% more). If broadcasting seed, tamp or press down the seed lightly into the soil (e.g. using a cultipacker, or a grass roller for smaller sites) after planting to ensure that seed has direct contact with the soil.

Using a native seed drill can be ideal for large sites with light stubble but sites must be level. If using a drill seeder, set the depth controls so that seeds are not buried more than 0.25" (6 mm) deep, which will affect establishment.

Hydroseeding is appropriate for sloped areas and hydromulch can be used to hold seed in place until germination can occur. If hydroseeding, apply the seed, mixed with a small amount of fiber or straw and tackifier first, then follow up with a second pass of hydromulch mixed with tackifier to hold it in place. This ensures seeds are covered by the hydromulch.

Consider including nurse or cover crops in seed mixes for sites where erosion control or rapid plant cover establishment is required. Nurse or cover crops in seed mixes help hold the soil while native species establish. Suitable nurse crops include sterile hybrids or annuals such as oats (*Avena sativa*), winter wheat (*Triticum aestivum*), or rye (*Lolium multiflorum*).

Check erosion control mulches or straw, seed laboratory reports, and legal seed labels of the planting stock. Mulches, seed, and other planting stock should be free of noxious weeds, invasive or introduced species, and other crop components.

Consider installing signage to indicate habitat in progress. Habitat planted with seed can take some time to establish, and a sign can explain future goals and that a planting is underway.

Require seed testing certificates from seed vendors. When planting seed, require seed testing certificates from seed vendors that describe germination rates and any weed seed or contaminants in the order.

When Installing Habitat via Transplants

Prepare for the planting before installation. Stage the planting before digging holes, considering the size of each species at maturity when spacing out plants. Select the most appropriate equipment for the site. Shovels are often adequate for excavating holes for many transplants, but power augers can be an efficient way to create a hole for large container stock.

Use compost and mulch where needed. In areas where soil is compacted or degraded, add clean compost (no manure or biosolids) to holes prior to planting. Avoid using sphagnum peat moss because of the impact on wetlands and the associated release of greenhouse gasses. Spread light layers of weed-free straw, bark, or wood chip mulch around the base of plants to reduce weed competition and to hold in moisture.

Irrigate the transplants thoroughly immediately after planting. Depending on weather, region, and site conditions, regular follow-up irrigation may be needed in the first year or two after planting, but can be discontinued after establishment.

Protect transplants from browsing animals. Install netting or other plant guards where needed to protect transplants from browsing animals that can cause significant damage.

Conduct Ongoing Maintenance of Pollinator Habitat Following Plant Installation

Manage weeds. Control annual weeds and any perennial weeds that were not eliminated before planting before they seed. Take care with plant identification, as some native wildflower seedlings may look similar to some weed seedlings. If needed, in the first year or two following establishment by seed, mow or reduce the canopy of weeds if they reach a density and height that is stunting the growth of the native plant seedlings underneath.

Conduct vegetation management as needed to maintain plant diversity. Plant communities need disturbances or vegetation management over time to reduce encroachment by undesirable species (weeds, certain woody plants) and maintain species diversity. Vegetation management techniques could include mowing, haying, grazing, or prescribed fire, and the most appropriate technique will depend upon the site conditions and management goals. Consider pollinator habitat needs in ongoing management (see other recommendations for more details).

Additional Resources

Native Plant Revegetation Guide for Colorado
Colorado Natural Areas Program, Department of Natural Resources
cpw.state.co.us/documents/cnap/revegetationguide.pdf

Native Plant Revegetation
Colorado State Parks
cpw.state.co.us/Documents/ResourceStewardship/NativePlantRevegetationPrescription.pdf

Ecoregional Revegetation Application Tool
Federal Highway Administration
Select by state or county to download native plant lists or filter for attributes such as value to pollinators.
www.nativerevegetation.org/era/

Native Plants for Pollinators and Beneficial Insects: Rocky Mountains Region
Xerces Society for Invertebrate Conservation
xerces.org/publications/plant-lists/native-plants-for-pollinators-and-beneficial-insects-rocky-mountains

Monarch Nectar Plants: Rocky Mountain Region
Xerces Society for Invertebrate Conservation
xerces.org/publications/plant-lists/monarch-nectar-plants-rocky-mountains

Guidance to Protect Habitat from Pesticide Contamination
Xerces Society for Invertebrate Conservation
xerces.org/publications/fact-sheets/guidance-to-protect-habitat-from-pesticide-contamination

Recommendations for Creating New Habitat That Are Unique to Built Environments

Roadsides

Consider salt tolerance in plant species selection. In areas with snow and ice, consider planting species with some level of salt tolerance close to the road in order to reduce plant damage from road salt applications.

Plant diversity can aid in heavy metal uptake. Including a diversity of wildflowers can reduce pollinator exposure to heavy metals and salts, as different plant species uptake pollutants at different rates.

Salvage key native plants before construction. When possible, salvage native plants from the site prior to construction and disturbance for use in the revegetation project, particularly those that are more difficult to establish or are longer lived. Enlist the help of other agencies or volunteers to relocate the salvaged vegetation temporarily for installation at the site after construction or for installation at another appropriate site.

Ensure lines of sight remain clear. Avoid taller herbaceous plants in areas where lines of sight could be blocked, such as intersections and other safety zones.

Consider where to prioritize using high-quality plant materials in revegetation projects to support pollinators. Resources are limited and prioritizing roadside sites that improve connectivity, that are wider, and with lower traffic density can improve the quality of roadside pollinator habitat. Medians are low priorities because they are often narrow and, due to their placement between roads, may create a higher risk for pollinators from vehicle mortality.

Additional Resources

Pollinator Habitat Conservation along Roadways
NASEM; TRB; NCHRP
Each volume includes a detailed plant list for that region.

- Volume 12: Northern Plains Region
  nap.nationalacademies.org/catalog/27088/pollinator-habitat-conservation-along-roadways-volume-12-northern-plains
- Volume 13: Rocky Mountains Region
  [...]/27121/pollinator-habitat-conservation-along-roadways-volume-13-rocky-mountains
- Volume 15: Southern Plains Region
  [...]/27119/pollinator-habitat-conservation-along-roadways-volume-15-southern-plains
- Volume 16: Southwest Region
  [...]/27118/pollinator-habitat-conservation-along-roadways-volume-16-southwest

Roadside Revegetation: An Integrated Approach to Establishing Native Plants and Pollinator Habitat
Federal Highway Administration
www.nativerevegetation.org/learn/manual_2017/chpt5_implementation/5_3_obtain_plant_mat.aspx

Landscaped Areas

Establish perennial ground covers. Reduce the amount of lawn that requires mowing by establishing drought-tolerant perennial blooming ground covers, such as pussy toes (*Antennaria* sp.), yarrow (*Achillea* sp.), fringed sage (*Artemisia frigida*), field chickweed (*Cerastium arvense*), kinnikinnick (*Arctostaphylos uva-ursi*), creeping Oregon grape (*Mahonia repens*), geranium (*Geranium* sp.), phlox (*Phlox* sp.), or winecup (*Callirhoe involucrata*).

Create new pollinator habitat gardens in public places. Gardens that include plants and host plants at public facilities, office buildings or other suitable locations can help the public learn more about pollinators and their habitat, as well as agency goals around pollinator conservation.

Limit the use of weed barrier fabric or thick layers of mulch. Weed barrier fabric can be impenetrable to bees trying to nest in the ground, and heavy layers of bark mulch or wood chips can likewise restrict the access of ground-nesting species to soil.

Adjust stem pruning to support tunnel-nesting bees. Leave stems standing where possible in winter (leaving flower heads will also help to support birds that eat seeds), and trim the stems in the spring, leaving at least 6 in. (15 cm) of length (aim for 8–12 in. [20–30 cm]). Cutting stems in the spring will give tunnel-nesting bees access to new tunnels, and they will use them through the growing season. The stems will degrade naturally by the time new stems are left standing the following season.

Additional Resources

Nesting and Overwintering Habitat for Pollinators and Other Beneficial Insects
Xerces Society for Invertebrate Conservation
xerces.org/publications/fact-sheets/nesting-overwintering-habitat

Pollinator-Friendly Parks: Enhancing Our Communities by Supporting Native Pollinators in Our Parks
Xerces Society for Invertebrate Conservation
xerces.org/publications/guidelines/pollinator-friendly-parks

State Pollinator Conservation Restoration of Existing Habitat, and Creating New Habitat Practices

Restoration and landscape design practice questions were included in the survey administered to state staff. A question assessing the frequency of use of restoration and revegetation practices resulted in 92% of the survey respondents indicating that their agency did implement these practices (sometimes, 21%; often, 39%; always, 32%). Another question assessed the relative feasibility of use of several specific pollinator practices and "increased use of native pollinator-attractive plants or seed mixes" garnered a high level of feasibility to implement (medium, 8%; high, 77%). To understand the use of more specific pollinator-restoration, revegetation, and landscape-design practices, the survey assessed the frequency of use of 12 different practices (see Figure 3.26 on next page). The most frequently used practice was "native plants are used in plantings," perhaps reflecting that several state departments have policy directives about using native plants in plantings (e.g., CDOT Procedural Directive 503.1 "Landscaping with Colorado Native Plant Species and Managing the Colorado Pollinator Highway"). The least-used practices are "irrigate for early plant establishment when needed," and "create new pollinator habitat gardens at public facilities, office buildings or other suitable locations." The lack of irrigation infrastructure for plantings that occur on dispersed state lands may help to explain the lower frequency of providing early irrigation when establishing plantings. There does appear to be a great opportunity and reasonably feasible option for creating new pollinator habitat by increasing the planting of pollinator habitat gardens at public facilities and offices. The benefit of doing so is that these locations can also serve as important demonstration sites and offer valuable outreach and education opportunities to the public. Other practices to target for increasing their use are the "least frequent" practices listed below.

More frequently used practices:

- Native plants are used in new plantings (*this was the most frequently used*)
- Require seed testing certificates from seed vendors
- Prioritize using locally or regionally sourced native plant materials
- Including three or more species in bloom at any time between spring and fall
- Include plants known to attract pollinators

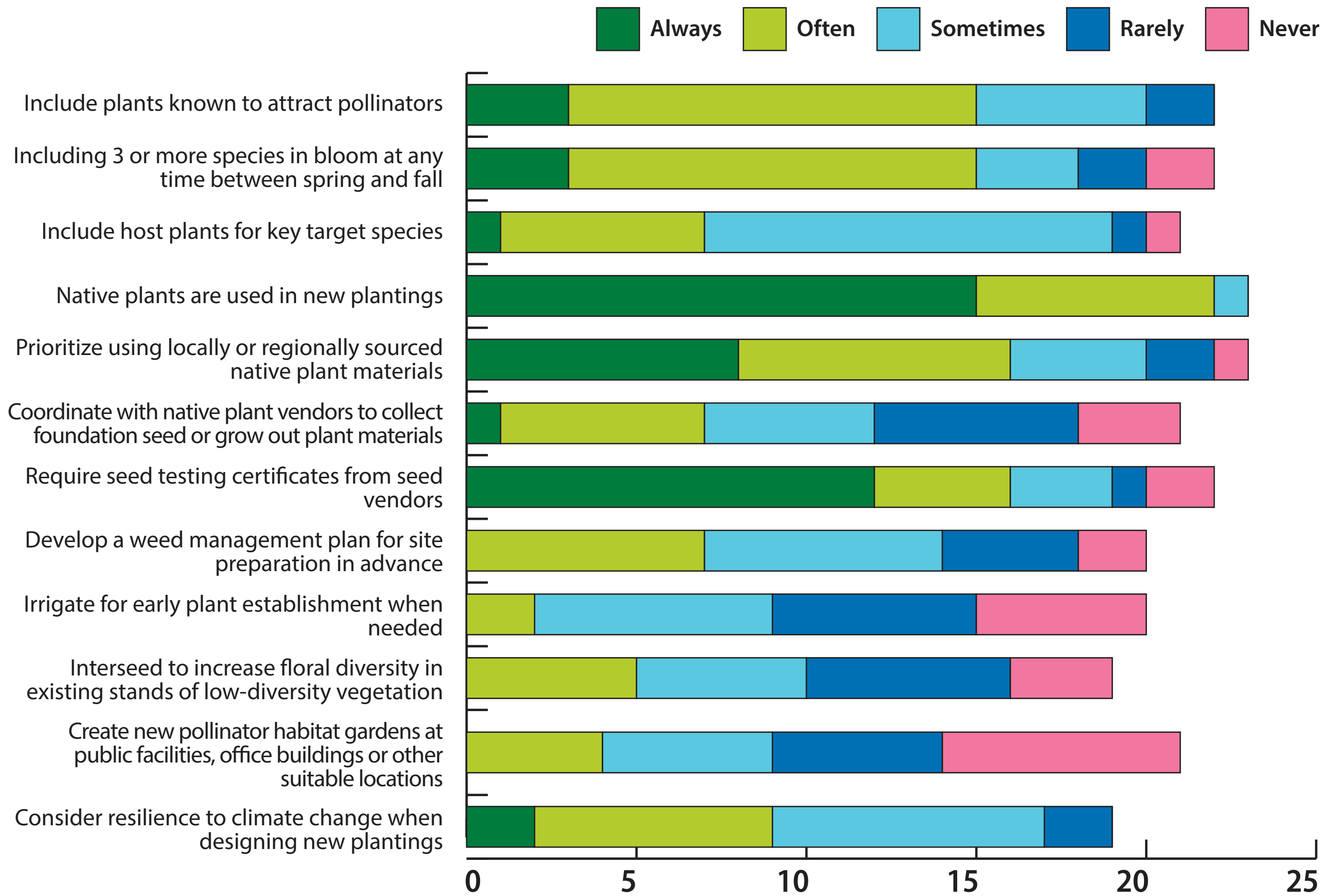
Somewhat used practices:

- Consider resilience to climate change when designing new plantings
- Develop a weed management plan for site preparation in advance

Least frequently used practices:

- Irrigate for early plant establishment when needed

Figure 3.26: How frequently does your agency currently implement the following landscape design and revegetation practices?



- Create new pollinator habitat gardens at public facilities, office buildings, or other suitable locations
- Coordinate with native plant vendors to collect foundation seed or grow out plant materials
- Include host plants for key target species
- Interseed to increase floral diversity in existing stands of low-diversity vegetation

Challenges & Barriers to Implementing Pollinator Conservation Practices for Restoring Existing Habitat & Creating New Habitat

Both survey results and staff interviews resulted in a great deal of interest by state staff in sharing ideas and the challenges they experience in restoring and creating native plant habitats. The survey had several questions directed at learning about challenges experienced by staff. Survey results for a question specifically about the challenges of establishing native plantings identified the following issues as the biggest challenges that prevented staff from being more successful:

- Weed control (either prior to planting or during establishment phase),
- Moisture availability (e.G., Irrigation for transplants), and
- Long-term maintenance plan for new plantings

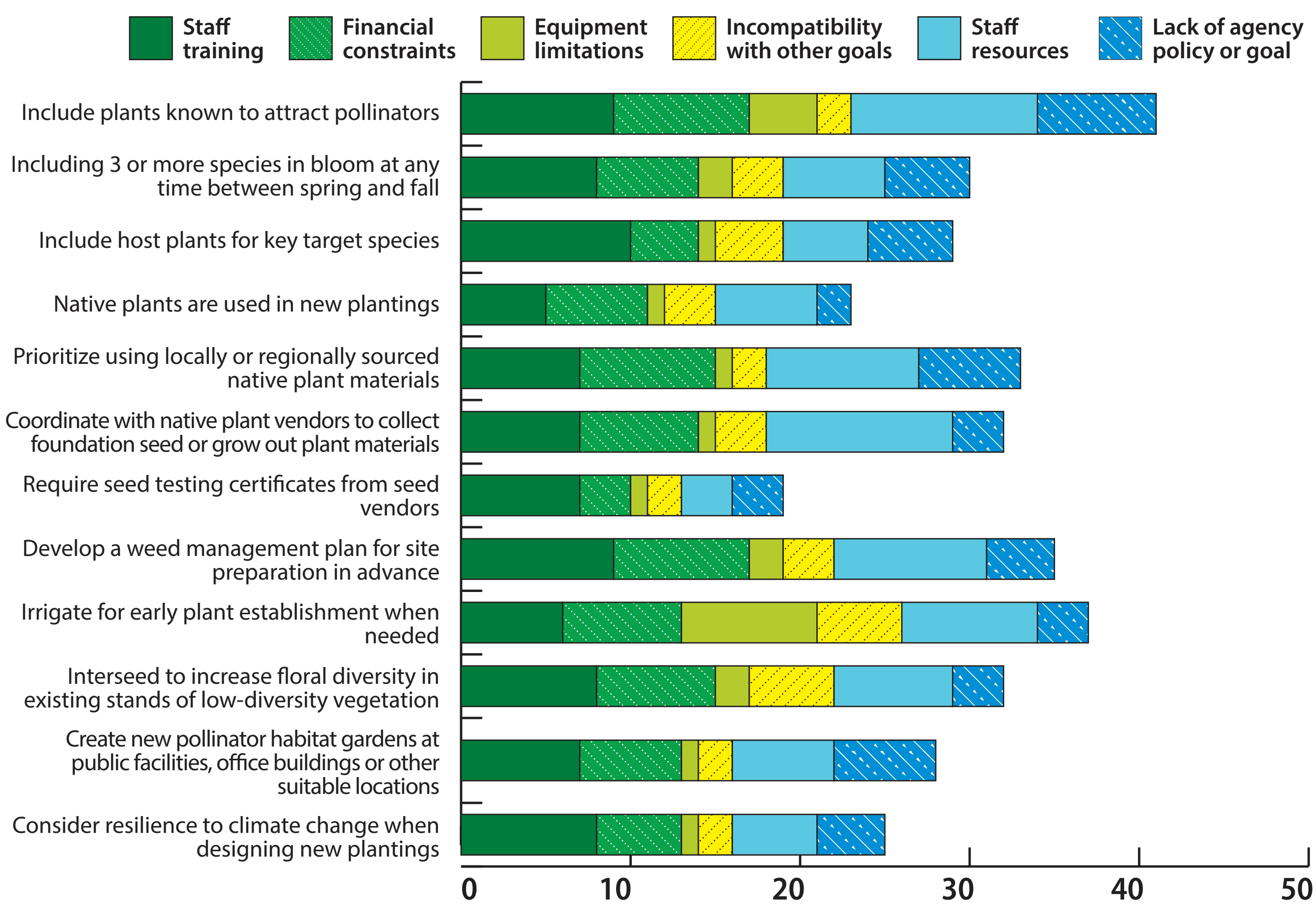
Other common barriers experienced by staff are provided in Figure 3.27 below. The barriers that presented notable challenges across many of the practices were a "lack of staff training" and a "lack of staff resources." Financial constraints were the next most common barrier. The remaining barriers asked about in the survey were a "lack of policy guidance," "incompatibility with other goals," and "equipment limitations," and these were comparatively less problematic for staff.

The lack of staff training is a common barrier across many potential management practices. Here it can likely be attributed to two factors: 1) a lack of staff awareness about a particular practice, and 2) a lack of knowledge about how to implement a practice. The practices where training is a more significant barrier include "requiring seed testing," "developing a weed management plan," and "considering climate change with designing plantings." Ensuring there is adequate training to support how to develop weed management plans and how to factor in climate change with designing plantings are topics on which to consider focusing training. More broadly across all of the practices, training can be a consistent barrier, and is therefore a key element to include in implementation planning for all the practices due to the complexity and skills required to implement most of the practices.

Additional challenges and barriers that were more commonly raised by staff through the survey and interviews, and important to highlight, include:

- Lack of high quality and readily available native plant materials and finding native plant and seed suppliers,
- Lack of consistent knowledge that can be shared about seed mixes and seed sourcing,

Figure 3.27: What are the barriers for your agency to implement the following landscape design and revegetation practices?



- Lack of funding (budget) is a huge constraint on maintenance sections and native forbs are expensive, and
- Lack of staff knowledgeable about revegetating areas with native plants. (Consultants are also often not knowledgeable. They may work in other states and specify plants that are native to the states they are more familiar with, but are not native to Colorado.)

In summary, the most important factors to support staff efforts to restore and create native plant habitat for pollinators is to ensure there is adequate funding and financial support, that there are adequate staff training opportunities and resources, and to ensure staff have the time and capacity to do the work.

3.2.8. Prescribed Fire Management

Prescribed fire is a land and resource management tool that can be used in a variety of Colorado's natural communities including grasslands, shrublands, woodlands, and forests for both ecological and wildfire mitigation purposes. Many of these environments have evolved with fire occurring at varying intensities, extent, and intervals. In general, pollinators benefit from prescribed fire when it effectively restores natural communities to the conditions under which pollinators evolved. The presence of fires in Colorado's landscapes over time has contributed to the diversity of plants, heterogeneous structure of vegetation, and diversity of animals, including pollinators, that inhabit the state.

As a management tool, prescribed fire can improve habitat conditions for pollinators by increasing plant abundance and diversity (Huntzinger 2003; Ponisio et al. 2016; Carbone et al. 2019). When used in fire-adapted forests and shrublands, prescribed fire can increase herbaceous flowering vegetation (Roundy et al. 2014; Bates et al. 2016; Bybee et al. 2016). In grasslands or open landscapes, prescribed fire can be an important tool for preventing the encroachment of trees and maintaining areas dominated by grasses and flowering plants. Prescribed fires, similar to wildfires, may benefit pollinators by causing a pulse in floral resources, or by increasing the abundance of flowering herbaceous vegetation that results in an increase in pollinator abundance (Moranz et al. 2014). As discussed in the Section 2.3.6 of the Scientific Review, the uptick may not persist through time.

Prescribed fire also has the potential to negatively impact pollinators through direct and indirect effects. As for direct harm, prescribed fire can cause mortality and threats to pollinators when they are in less-mobile and more-vulnerable life stages and unable to escape. This can be important for some grassland-dependent pollinators with restricted ranges or narrow habitat requirements. There are examples of this in the Midwest where prescribed burns have caused the loss of grassland specialist butterflies such as regal fritillaries (*Argynnis idalia*) and arogos skippers (*Atrytone arogos*) from specific sites (Swengel 1996; Swengel et al. 2010). Other examples where direct impact or harm can occur are for pollinators such as bees that nest in wood or plant stems, such as those of wild rose or sumac. Not only may they suffer direct mortality, stem-nesting bees may be more challenged after a fire to find alternate stems to nest in and populations may need a longer recovery period (Potts et al. 2003; Cane and Neff 2011).

Fire may also have an indirect negative influence on pollinators if they occur at the wrong scale, time, or location, and cause impacts that take native plant and pollinator communities years or decades to recover from. Including an entire habitat in a prescribed burn can remove enough available habitat to harm a local invertebrate community (Cane and Love 2016). Thus, for pollinators it is often better to avoid burning

Figure 3.28. Low-intensity prescribed burn moving through the understory of a ponderosa pine (*Pinus ponderosa*) forest. (Photo: Mark Rose.)

an entire habitat all at once, leaving unburned adjacent areas and skipped areas within the burn (Black et al. 2011). Unburned areas can serve as refugia, provide pollinators with post-burn forage and nesting materials, and reduce the stress of lost resources—while also allowing the habitat to gain the benefits of fire. When used as a management tool, prescribed fire should be planned as part of a rotational burn system, where small sections are burned in multiyear or multi-decade cycles, ideally mimicking more naturally occurring historic fire frequencies.

The season or timing of a prescribed burn can influence plant and pollinator communities. For instance, a prescribed burn timed in spring will likely negatively impact cool-season grasses and early-season wildflowers, and benefit the growth of warm-season grasses and summer and fall wildflowers. Springtime pollinators would face a reduction of early-season nectar and pollen sources, but the likely increase in foraging resources from more abundant summer and fall blooms would help pollinators remain active later in the year.

On rangelands, consider integrating prescribed fire into grazing management plans through patch-burn grazing when and where this may be possible and beneficial for the type of rangeland being managed. A patch-burn regime attempts to mimic the natural interactions between fire and native grazers, where fire affects grazing patterns and grazing patterns affect the intensity and size of fires. As grazers prefer the more palatable post-fire plant growth, they leave more vegetation in less preferred and less grazed areas, which creates more fuel in these sites when they are burned. The interaction causes a changing matrix of plant communities and vegetation structure. The goal would be to burn one-third of each established patch-burn grazing unit every year on a three-year rotation.

While there is an ongoing need to understand more about how prescribed fires help or affect pollinators, especially in the diversity of environments occurring in Colorado, the following recommendations should be considered to support pollinators when prescribed fires are planned.

Recommendations for Prescribed Fire Management

The use of prescribed fire as a land-management practice includes many constraints and complexities that must be addressed before a burn can occur. The complexities around safety, feasibility, permit requirements, environmental conditions, policy guidance, and the availability of adequate firefighting equipment and personnel are just some of the considerations that need to be addressed and managed. These complexities likely make it difficult for state agencies to use prescribed fire, and as a result it is an infrequent practice. But for situations where and when it is possible, these recommended practices can help to integrate pollinator conservation into burn planning. Considering these practices will help pollinators cope with the disturbances caused by a prescribed fire and benefit from the intended ecological benefits that result.

Manage Prescribed Fire Size and Frequency to Allow Recovery

Burn one third or less of a habitat or management area. Burn only small sections of a habitat or management unit at a time. In order to reduce the likelihood that a pollinator population will be unable to recover, and to speed up recolonization of the area burned, plan burn units to be less than one third of the area or habitat that will be burned.

Consider the natural fire interval of a site when planning burn frequency. Consider site-specific natural or historic fire intervals for the type of ecosystem and site when determining the intervals for prescribed burns. More fire-prone ecosystems like grasslands may have more frequent intervals, however, avoid burning the same location every year. Plan for intervals of at least 3–10 years or longer, depending on the natural frequency, so that impacted pollinator populations have an opportunity to recover. Factoring the fire-burn frequency across a landscape will also help determine how best to sustain and increase habitat heterogeneity at multiple scales within and among sites

Leave small unburned areas. In fire prescriptions and during the management of the fire as it moves through an area, allow the fire to leave small unburned areas ("skips"). The unburned areas should be left intact as potential micro-refuges, unless they need to be managed otherwise for safety reasons. Even small patches of unburned habitat are helpful.

- If possible, mow, reduce woody fuels, or create fire breaks that will result in patches of unburned or lightly burned areas to serve as refugia for animals within the burn area.
- Pollinators differ by their ability and the distance they are able to disperse. This is an important factor to integrate when considering refugia in prescribed fire management planning.
    - » Solitary bees: 100 yards (100 meters) to 1 mile (1.6 kilometers)

- » Bumblebees: several hundred yards (meters) to several miles (kilometers)
- » Butterflies: varies from several hundred yards (meters) (some Lycaenidae) to thousands of miles (kilometers) (monarch, painted lady).

Avoid burning small isolated habitat fragments. Small or isolated habitat fragments could have unique or uncommon plant communities and pollinator associations, and no refugia from adjacent areas to help recolonize.

When planning burns in locations with imperiled pollinators, it is especially important to leave suitable and occupied habitat unburned. In locations with imperiled pollinators, it is important to be even more careful about not burning more than one third or less of the potential habitat to reduce the risk of local extirpation. Additionally, manage burns so that the burn does not fragment remaining suitable habitat at a scale that ends up isolating remaining pollinator populations. As an example, some butterflies may be only able to disperse a few hundred yards (meters) and if unburned areas are not close enough for dispersal, the remaining populations may be stranded and not able to cross to other unburned areas, and thus, become more vulnerable.

Take Lower-Impact Actions

Minimize the use of heavy equipment to reduce ground disturbance. Reduce and avoid, if possible, the use of heavy equipment or other actions that could cause excessive disturbance to soils. Minimizing ground disturbance can help protect ground-nesting sites and overwintering sites for bees and other pollinators.

Reduce or avoid high-intensity fires. Avoid high-intensity fires by burning when humidity is highest during the day (e.g., early morning) and keeping fire out of areas with high fuel loads. Burning in the morning when humidity is higher and temperatures are lower may increase the heterogeneity of a burn and help leave some unburned refugia and may reduce soil heating which can increase mortality to invertebrates (Hill et al. 2017). Reducing opportunities for high-intensity fires that cause extremely hot soil temperatures can threaten nests and overwintering sites below the surface of the ground. Lower intensity fires and less soil heating may also favor more rapid vegetation recovery. Ultimately the primary resource management goals of a prescribed fire will determine the necessary fire conditions to achieve the planned objectives. There may be some cases where a high intensity fire may be appropriate and needed to restore a natural community to its pre-Columbian state.

Carefully locate and time wood and slash pile burning. The piling of slash or other woody materials and then burning the piles when weather conditions allow is a common practice associated with forest fuel reduction efforts. Ideally, piles should be located in areas away from known sensitive pollinator sites and not placed in or near habitat with high plant diversity, such as meadows, springs, and riparian areas.

Additional Considerations for Imperiled Species

Develop specific prescribed fire management objectives for imperiled pollinators. Using the best available information regarding the type of habitat, the prescribed fire goals, and the possible effects of fire on adult and larval stages, develop objectives in the prescribed burn plan to minimize risks to the imperiled species. Evaluate both the benefits and risks of managing the habitat of an imperiled pollinator with fire to help make decisions around the appropriateness of using fire. A rare species with a very restricted range and limited dispersal ability may be very vulnerable to a burn in its habitat and take years to recolonize.

Monitoring the effectiveness of prescribed fire. Establish and conduct before- and after-fire monitoring to assess the effects of prescribed fire on pollinator communities. This is even more important if vulnerable or imperiled species are involved. Monitoring can also help to determine whether using fire as a resource management tool is achieving desired management goals and increasing habitat quality for pollinators.

State Prescribed Burn Management Practices

State staff were surveyed regarding the frequency of using prescribed fire as a land management tool. Given the complexities and challenges associated with prescribed fires, it was not surprising that 43% of the survey respondents indicated they "never" use it, 27% only "rarely", and 19% "sometimes." Only 11% said they "often" or "always" used prescribed fire. During staff interviews, it was pointed out that using prescribed fire as a management tool was more challenging to implement in comparison to considering other options, and in particular required a lot of hoops to be jumped through. This in part contributed to the infrequent use, and to the perspective that it's unlikely to be an approach that becomes more frequently used.

> "Prescribed fire is just another tool in the toolbox, but it's not always a perfect fit. When it is a viable option, we can incorporate timing of the burn, the season in which the burn takes place, and the intensity of the burn to improve the landscape for occurrence and/or diversity of plant species that may be a benefit to the pollinators."
>
> \- Colorado Native Pollinating Insects Health Study Agency Interview Participant

Staff were also asked in the survey about the feasibility of implementing a recommended practice of limiting prescribed fires to at most one third of the habitat burned in a single growing season. This practice is often more applicable for faster recovering habitats such as grasslands. Nearly 60% of the respondents indicated that prescribed burning was not applicable, understandable with fire not being a viable option for many agencies. The feasibility for agencies where it is applicable, was rather evenly split between low to high feasibility (low, 15%; medium, 13%; high, 13%). These results also likely reflect the broad range of habitats in Colorado where prescribed fire is potentially used and the scale or size of burns relative to the type of habitats. Potentially increasing the medium-feasibility circumstances to high-feasibility situations may be a way to target increasing the implementation of this particular practice. It's likely that low-feasibility circumstances have more barriers that reduce feasibility and make these situations more difficult to accomplish this practice.

Challenges & Barriers to Implementing Prescribed Fire Practices

The surveyed staff were not asked questions about the potential barriers to implementing pollinator conservation practices related to prescribed fire management. Interviewed staff, however, were asked to share information about agency practices. One of the most important points raised was the role that established habitat or resource goals have in dictating burn plans and what resource priorities to focus on. In planning burns, a crucial step is working with subject matter experts (ecologists, forest or range managers, biologists, etc.) to establish objectives for how fire will be used as a tool to manage the landscape. If pollinator conservation objectives are identified as part of the resource management objectives, fire managers and planners are then able to write fire prescription practices and objectives to achieve desired outcomes for pollinators. Where applicable, an important first step in improving how prescribed fire practices and management can benefit pollinators and their habitats, is to ensure pollinator-related information and goals are established for habitats that may be burned so that these goals can be integrated into prescribed fire plans and actions.

3.3. State Agency Pollinator Programs, Policies, and Recommendations

3.3.1. Summary of Existing State Agency Programs & Policies Related to Pollinator Conservation

Pollinators, critical to the health of ecosystems and the agricultural industry, have faced growing threats to their ability to thrive. Several state agencies have recognized the urgency of conserving these invaluable species and have implemented a diverse array of programs and policies to address this issue. Through surveys and interviews with state agency representatives, this summary delves into the various programs, initiatives and policies enacted to conserve and promote pollinators and their related habitats.

State employees from several agencies (CDA, DFPC, CDOT, CNAP, CPHE, CPW, DNR, SFS, and SLB) are engaged with pollinator conservation at varying levels. Many agencies do not have direct policy or funding to actively support invertebrate pollinators. However, pollinator conservation still frequently fits within the land management or sustainability goals in which they participate, especially the agencies involved with land reclamation, restoration, conservation, and agricultural responsibilities. Representatives from some of these agencies attend and present at the annual Colorado Pollinator Network (CPN) Pollinator Summit. Examining the existing efforts at the state agency level allows for a better understanding of the state's commitment to pollinator conservation and the approaches taken to safeguard these vital pollinators. It also provides an opportunity to assess and identify where expanded efforts or new programs and policies can contribute even more to the state's ability to leverage its resources to ensure the health of native pollinating insects and their habitats.

3.3.2. Colorado Department of Transportation

Existing Programs & Policies

The Colorado Department of Transportation (CDOT) has developed several programs and policies dedicated to the protection and enhancement of pollinators. These initiatives span a diverse range of efforts from habitat restoration and pesticide management to education. CDOT tries to incorporate pollinator-friendly native species in all seed mixes and restoration and mitigation efforts. The primary goals of CDOT are success in habitat restoration, erosion control, wetland mitigation, mowing, and mitigating greenhouse gas emissions. Pollinator conservation is not currently formally included in management policy, however, it is still being considered when possible. Funding for specific pollinator-focused projects (such as I-76) does exist. This summary explores the various programs and policies that promote the well-being of pollinators.

I-76 Colorado Pollinator Highway Project

- **Description:** A CDOT commitment to preserving, enhancing, and creating pollinator habitat along the Colorado highway system.
- **Benefits to Pollinators**: Supports pollinator habitat through Integrated Roadside Vegetation Management guidelines and brings public awareness to pollinator conservation by renaming I-76 as the "Colorado Pollinator Highway." Increases forage resources and nesting sites for bees, butterflies, and other pollinators.
- **Link:** www.codot.gov/programs/environmental/landscape-architecture/pollinator-program/i-76-colorado-pollinator-highway-project-1

Case Study: Colorado Pollinator Highways

Colorado's Pollinator Highways are a great example of success in incorporating pollinator conservation into transportation infrastructure projects. The Pollinator Highways initiative has involved transforming the rights-of-way along a stretch of interstate and a section of highway rights-of-way into native pollinator habitats, showcasing how highways can be used to support pollinators and balancing transportation needs with environmental and community concerns. This case study describes the work done to improve pollinator habitat at two locations, the Julesburg Pilot Project and the Diagonal Highway.

Figure 3.29. Colorado Department of Transportation staff collaborate with community volunteers to plant native species for the I-76 Pollinator Highway and Welcome Center project. (Photo: CDOT).

Julesburg Pilot Project: I-76 Pollinator Highway and Welcome Center

The Julesburg Pilot Project, also known as the I-76 Pollinator Highway, was the first Pollinator Highway in Colorado. It is an ambitious effort in which CDOT and multiple partner organizations (including local and statewide nonprofit pollinator interest groups) converted four miles (six and a half kilometers) of highway interstate right-of-way to pollinator habitat. CDOT Landscape Architects and Biologists developed a list of 16 wildflower species based on field identification and research of local native plants and commercial availability of seeds. Approximately fifty volunteers hand-seeded the project site. The planting has been continuously monitored by CDOT staff and volunteers from the People and Pollinators Action Network every year since its establishment to better understand establishment dynamics.

Figure 3.30. Native wildflower species planted along I-76 as a part of the Pollinator Highway and Welcome Center Project. (Photo: CDOT.)

The I-76 Pilot was initiated in 2018 and was funded entirely through direct donations to the project. Several businesses, public agencies, and private interest organizations donated supplies or services such as seed, volunteer lunches, t-shirts, bumper stickers, personal safety equipment, transport vans, technical support, staff time, hospitality, public relations or communications support, graphic expertise, and volunteer labor. CDOT and partner organizations intend to engage in ongoing leadership that will fully realize the vision of the Colorado State Legislature to implement and sustain the Colorado Pollinator Highway.

Diagonal Highway: Colorado State Highway 119

The second Pollinator Highway in Colorado is the Diagonal Highway (Colorado State Highway 119) in Boulder County. Planting occurred in the fall of 2022 and included a mix of 15 wildflower and 6 native grass species native to Colorado and adapted to the local ecoregion in Boulder County. To provide maximum benefits to as many pollinators as possible, the selected forbs species have a wide diversity of colors and bloom times, including native milkweed species to support monarch butterflies.

Figure 3.31. Native wildflower species planted along Colorado State Highway 119 as a part of the Diagonal Pollinator Highway Project. (Photo: CDOT.

Landscaping Requirements and Colorado Pollinator Highways Procedural Directive 503.1

- **Description:** Native grasses and forbs are to be specified along all rights-of-way and non-irrigated landscapes. Use of non-natives can be used in irrigated landscapes and water-wise plantings are encouraged to reduce water use. Recognizes I-76 as the first Colorado Pollinator Highway.
- **Benefits to Pollinators**: Supports native pollinators with native floral species. Native seed mixes have evolved to include more forbs. Increases forage resources and nesting sites for bees, butterflies, and other pollinators. Includes CDOT Operation and Maintenance practices to promote pollinator habitat.
- **Link:** www.codot.gov/programs/environmental/landscape-architecture/pollinator-program

CDOT Pollinator Habitat Enhancement Plan (2020)

- **Description:** Provides technical training and landscape architectural expertise for a variety of project and program needs including roadside restoration and native revegetation, stormwater management, visual impact analysis, specifications, erosion control, and statewide regional environmental design and planning support.
- **Benefits to Pollinators**: Prioritizes habitat enhancements, such as introducing native forbs in revegetation efforts, that support pollinator conservation.
- **Link:** www.codot.gov/programs/environmental/landscape-architecture/pollinator-program/cdot-pollinator-videos-and-plan

Living Snow Fences Research Project

- **Description:** Living snow fences (trees and shrubs) alter wind speed and direction, causing snow to settle in designated areas, and protecting roadways, structures, livestock, and wildlife.
- **Benefits to Pollinators**: Living snow fences are often left undisturbed and include native trees and shrubs upon which pollinators can forage. These areas can provide refuge for pollinators.
- **Link:** www.fs.usda.gov/nac/assets/documents/workingtrees/brochures/livingsnowfenceforweb.pdf

Integrated Roadside Vegetation Management Plan (IRVM) 2020

- **Description:** This manual represents CDOT's approach to roadside management from primarily a traditional mechanical and chemical regime to an Integrated Roadside Vegetative Management (IRVM) approach
- **Benefits to Pollinators**: Section 6 clearly outlines managing vegetation for pollinator species. This includes reducing mowing, using IRVM to address weed and pest pressure, enhancing habitat with native forbs, and adapting management to support sensitive species. So far, 28 counties and 910 mi. (1465 km) of road (1820 mi. [2930 km] of CDOT rights-of-way) have some sort of protection for plants of concern (see figure 4.1). Pollinator highways can be added to these miles and similar protections given.
- **Link:** n/a

CDOT Seed Calculator (in development)

- **Description:** Seed calculator for determining potential native seeds based on ecoregion, soil salinity, and other measures for project-specific seed mixes.
- **Benefits to Pollinators**: Calculator includes forbs and shrubs for pollinators.
- **Link:** n/a

Since at least 2017, all engineering projects that involve ground disturbance include funding for vegetation restoration with specifications and existing Procedural Directive 503.1 "Landscaping with Colorado Native Plant Species and Managing the Colorado Pollinator Highway" specifying that all vegetation along right of ways must be native and include pollinator forbs where feasible. CDOT Regions have also revised seed mixes to include greater percentages and increased diversity of native pollinator-friendly forbs and wildflowers specific to the ecoregions of the respective projects. CDOT conferenced on the monarch butterfly, which is a candidate species under the US Endangered Species Act, and created conservation measures to avoid and minimize impacts from projects on the monarch. CDOT Landscape Architects are implementing education and more discussion on how CDOT can contribute to pollinator conservation. CDOT also regularly complies with the Lady Bird Johnson American Beautification Act.

Potential New Program & Policy Recommendations

Continue to implement the CDOT Pollinator Habitat Enhancement Plan and increase the extent of pollinator habitat along the Colorado Pollinator Highway and increase the number of other roadway pollinator habitat projects to increase the overall extent of roadside pollinator habitat.

- **Description:** The designation of I-76 as the "Colorado Pollinator Highway" through 2017 House Joint Resolution 17-1029 and implemented through CDOT's Procedural Directive #503.1, which established landscaping and maintenance requirements for Colorado Pollinator Highways, and the CDOT Pollinator Habitat Enhancement Plan have resulted in projects which have created pollinator habitat and increased public awareness and involvement in pollinator conservation efforts. Another project along the Diagonal Highway in Boulder County has also recently been established to create pollinator habitat. These are great examples of collaborative efforts with local governments, businesses, and local and national pollinator organizations to increase habitat along Colorado's roadways. Opportunities to increase the extent and number of similar projects should be pursued, funded, and supported. Explore ways to enhance signage about pollinator roadway habitat and explore possible collaborative funding sources.
- **Staff Idea:** Yes
- **Rationale/Comments:** Staff surveys and interviews highlighted the importance of having policy guidance to prioritize and support the work of the agency to make on-the-ground pollinator habitat improvements. The intent of the policy and plan is to have ongoing projects and support for staff efforts to continue to implement habitat improvements along I-76 and along other roadways. It's important for CDOT to maintain the momentum of developing capacity and expertise to care for the habitat that has been established, and to prioritize new opportunities for habitat establishment with local, state, and national organizations.

Create plant specialist positions to support implementation of the Procedural Directive 503.1 "Landscaping with Colorado Native Plant Species and Managing the Colorado Pollinator Highway" and to assist project and operation managers with native plant seeding or planting recommendations and establishment.

- **Description:** Consider creating and hiring plant-related positions including a native plant specialist and restoration specialist for CDOT staff to consult or collaborate with on their projects and programs to guide the appropriate selection and establishment of native vegetation (and pollinator important plants).
- **Staff Idea:** Yes
- **Rationale / Comments:** The selection of site-appropriate native vegetation for projects requires specialized knowledge and experience with Colorado environments. A dedicated specialist with this knowledge and experience was identified as an important gap by agency staff. The lack of this

available expertise for staff to consult and the reliance often on contractors or consultants with less familiarity with Colorado-specific habitats and vegetation have resulted in inefficiencies and vegetation being established that are not within the range of native vegetation for the site.

Prioritize implementation of CDOT's current Integrated Roadside Vegetation Management (IRVM) practices and integrate content from this study and other related studies, so that it has the most current pollinator conservation practices.

- **Description:** CDOT has a very good IRVM guide that directs integrated pest management practices and other best management practices for vegetation management activities. The practices and standards included in the IRVM should continue to be supported and integrated into operational activities and training. This study and other recently completed guides such as the Pollinator Habitat Conservation along Roadways, Volume 13: Rocky Mountains Region, may have new information and practices which are not in the current version and should be added during the next update. An existing objective of the IRVM is to reduce the use of herbicides. Adding and emphasizing the importance of actions that avoid, limit, or mitigate the need to use pesticides is another important focus for the next update.
- **Staff Idea:** Yes
- **Rationale / Comments:** The IRVM is an excellent source of information and guidance for an integrated and ecological approach to vegetation management along CDOT managed roadways. The implementation of practices in the guide will improve the ecology of roadside habitats and result in improved pollinator habitat. Without adequate funds, staff support, and prioritization from all levels of the organization, implementation may not achieve desired results. Continued emphasis on implementing these practices, and filling any management gaps with new information, will help to achieve even better results.

Collaborate with CPW, SFS, SLB and other state agencies that purchase native seeds and plants and coordinate working with native plant growers and seed suppliers to align and leverage the state's purchasing influence to improve the supply of native plant materials.

- **Description:** Multiple state agencies acquire native plant seed and plants to use in restoration, revegetation, and habitat creation projects. Collaboration and coordination between the state agencies around their purchasing needs, determining what's available or not by potential suppliers, and leveraging their purchasing influence to improve supply, could help growers and suppliers increase their capacity to plan for and provide a greater supply of native plant materials. A coordinated effort can help to build relationships with suppliers and growers so that they can better understand the state's needs and meet those needs. Coordination may also help encourage the propagation of new native plants and seed stock that may not otherwise be available.
- **Staff Idea:** No
- **Rationale / Comments:** State staff indicated that some of the challenges they face with restoring or establishing native plant communities through habitat improvement projects is sourcing an adequate supply of native plants or seed that are appropriate for the location of the project. In addition to a lack of supply, the type of native plants available may not be regionally appropriate as natives, and thus, the project may not be able to achieve the full benefits from native vegetation establishment as planned. This can lead to less valuable resources for pollinators and even potentially greater dependence on the need to use non-native plants or native plants and seeds that are not regionally appropriate

Improve capacity to map, track, and keep current information about priority invasive and noxious weeds.

- **Description:** Enhance capacity to map, monitor, and keep updated information about type, location, extent, and trends of priority invasive and noxious weeds.
- **Staff Idea:** Yes
- **Rationale / Comments:** Department is often reliant on contractors or county quantitative information to document, monitor, and map noxious weeds. There are often gaps in the information available resulting in less responsive and effective management. Improved capacity to collect and track information could improve IPM management practices.

Increase training and use other tools to improve the ability of operation crews to identify important native plants and noxious weeds.

- **Description:** Increase training and develop or use other tools to help crews become more knowledgeable about native plants and noxious weeds. Ask about ideas of how to integrate conservation practices into their work.
- **Staff Idea:** Yes
- **Rationale / Comments:** Create networking and skill-building opportunities where knowledge can be shared and practices improved through collaborative training and idea exchanges.

Develop a map that shows where the habitat of pollinator species of special concern overlaps with state highways.

- **Description:** Collaborate with CPW to develop a map that shows where state roadways intersect with the habitat of pollinator species of greatest conservation concern and other vulnerable or important pollinator species. Distribution maps of many imperiled and listed pollinator species are available through the National Highway Cooperative Research Program's Pollinator Habitat Conservation along Roadways regional guidebooks, found here: www.trb.org/NCHRP/NCHRPWOD362.aspx. (The Rocky Mountains, Southwest, Northern Plains, and Southern Plains regions are all relevant to Colorado.)
- **Staff Idea:** Yes
- **Rationale / Comments:** CDOT staff are interested in understanding more about how habitats adjacent to state highways might be best managed to benefit the pollinator species in greatest need of conservation. Better information about the roadway locations that are most important for these pollinators would help prioritize and target habitat improvement projects.

Other Potential Opportunities & Concerns That Were Identified

- Budget! Funding is a huge constraint on maintenance sections and native forbs are expensive. Funding could allow for more seed mixes (ideally three mixes per zone) and better monitoring.
- Reliance on contractors for landscape design projects resulting in less focus on integrating site-appropriate native plants and habitat considerations into project designs.
- Weed applicators in Region 1 are also revegetation experts; pursue making this a department-wide practice.
- Develop practices for timing mowing for when it may be more advantageous for native grasses and forbs.

- Have staff knowledgeable about native vegetation and pollinator conservation practices schedule meetings with maintenance patrols to discuss practices, concerns, and opportunities for improvement.
- Assess and integrate into the Adopt-a-Highway program opportunities to include a pollinator-habitat focus and establishing native plant habitats along roadways. Volunteers could help with invasive plant removal, native seeding and planting, and conduct community science inventories. See Pennsylvania's Adapt and Beautify and Keystone Pollinator Habitat programs as an example.
- Establish "No Mow" pollinator habitat zones with designated signage to mark boundaries and inform the public about the zones and their purpose. See www.como.gov/public-works/street-division/pollinator/pollinatorfaq/
- Look into adding some type of seeding device to mowers to assist with spreading native seeds while mowing.
- Create native plant and pollinator training and herbicide management videos to help supplement in-person training and help with staff turnover, training, and onboarding.
- Establish native plant and pollinator habitat site monitoring to learn more about the efficacy and outcomes of projects.
- Incorporate additional Colorado native plants into new plantings, prioritizing key host plants of butterflies and moths and important nectar and pollen plants for bees. Regional plant lists that could be good starting points are available through the National Highway Cooperative Research Program's Pollinator Habitat Conservation along Roadways regional guidebooks (www.trb.org/NCHRP/NCHRPWOD362.aspx). The Rocky Mountains, Southwest, Northern Plains, and Southern Plains regions are all relevant to portions of Colorado.
- Consider participating in the Monarch Candidate Conservation Agreement with Assurances (CCAA).

3.3.3. Colorado Department of Natural Resources

Existing Programs & Policies

The Colorado Department of Natural Resources (DNR) has a broad statutory mission to manage the state's natural resources through six regulatory divisions. While state statutes acknowledge DNR's authority to manage native species, there isn't regulatory or management authority provided to Colorado Parks and Wildlife (CPW), a division of the DNR, to manage pollinators as wildlife. The DNR did establish a Pollinator Conservation Policy (Admin Order DNR-108) in 2018 to provide policy guidance for considering pollinators when possible and relevant and minimize negative impacts to pollinators. The goals of the Colorado DNR closely align with pollinator conservation. Introducing pollinator-focused policies and programs into the management strategies of Colorado DNR and the regulatory Divisions could be highly effective for pollinator conservation.

Pollinator Conservation Policy Administrative Order DNR-108

- **Description:** Encourages and supports the success of pollinators in Colorado and recognizes the important role that they play. The order instructs DNR Divisions to undertake actions, when possible and relevant and within existing appropriations, that support pollinators and minimize negative impacts to pollinators. Requires annual reporting on accomplishments and incorporating pollinator-friendly provisions into relevant policies and best management practices.

- **Benefits to Pollinators**: The order requires DNR Divisions to consider pollinator conservation when making habitat management decisions and when developing pollinator conservation strategies, and to incorporate pollinator conservation strategies in property management.

Potential New Program & Policy Recommendations

Evaluate the potential funding needs associated with implementing recommended policies, programs, new staff positions, and other actions needed to improve state efforts to conserve pollinators.

- **Description:** Develop a strategy to assess the funding necessary to implement recommended policies, programs, and practices addressed in this study. The strategy should include an evaluation of the potential funding needs, a prioritization of those needs, and an assessment of potential funding sources, so that adequate financial resources are available to support the implementation of the priority actions.
- **Staff Idea:** Yes
- **Rationale / Comments:** This report includes an extensive assessment of existing state agency programs and policies related to pollinator conservation and recommendations to enhance the effectiveness of state actions to conserve pollinators. Some of the recommended actions will require assessment of the funding support needed for implementation, including the expansion of existing programs, the development of new programs, and the addition of staff positions that would provide expertise around conserving pollinators and their habitats. An assessment and evaluation of the funding needs, prioritization, and identifying potential sources of funding would ensure that there can be appropriate funding to support successful implementation of priority actions.

Evaluate and pursue statutory authority for the management of bees, butterflies, other pollinators, and all invertebrates as wildlife.

- **Description:** Evaluate potential options and recommend an approach where DNR and/or CPW can be provided the statutory authority for managing invertebrates, including pollinating insects, as wildlife. Also evaluate the potential of considering statutory authority for native plants.
- **Staff Idea:** No
- **Rationale / Comments:** The DNR and CPW are vital for the conservation of Colorado's wildlife. Conservation actions by these agencies can effectively recover vulnerable wildlife populations, circumventing the need to list species under the US Endangered Species Act. Additionally, federal funding for species research and conservation is often tied to species that are listed as Species of Greatest Conservation Need (SGCN) in the State Wildlife Action Plan (SWAP). Yet, these agencies do not currently have management authority over bees, butterflies, and other pollinators because these animals are not defined as "wildlife." The state of Colorado should consider defining all invertebrates as wildlife under state code, which would allow the DNR and CPW to effectively work to conserve essential pollinators. Additional context and information available in Black and Jepsen (2023).
    - » Colorado's SWAP includes information about imperiled native pollinating insects in the plans appendix because the State lacks specific language granting conservation authority for the management of insects (and plants) to CPW or any agency or department. This creates a significant policy gap in the state's ability to prioritize, fund, and manage pollinators and the plants that both support and depend on pollinating insects. Granting specific authority is extremely important to promote and provide tools for the state to better protect at-risk

species and their habitats. Establishing clear management authority for pollinators, insects, and all invertebrates could provide an important tool to empower state pollinator programs and improve access to external funding.

Explore collaborative approaches and partnership opportunities with CDOT to establish pollinator habitat corridors.

- **Description:** Look into opportunities where DNR and CDOT can partner on efforts to conserve and enhance pollinator habitat corridors. Formalize the terms of the partnership through memorandums of understanding when feasible.
- **Staff Idea:** No
- **Rationale / Comments:** The DNR and CDOT have partnered on efforts to conserve Colorado's big game winter range and migration corridors and established a memorandum of understanding between the two departments to formalize their collaboration. The collaboration includes data sharing agreements. Roadways provide significant opportunities for pollinator habitat and corridors. The I-76 Pollinator Highway designation is an example of this. Collaborative approaches between the two agencies to identify important roadway pollinator habitats, and working together to maintain and enhance the ways the roadways serve as pollinator habitat corridors, could have significant benefit for pollinators.

Other Potential Opportunities & Concerns That Were Identified

- Assess and create a native seed acquisition subsidies fund to incentivize the use of native plants and seeds. Native plant materials can be prohibitively expensive at large scales. Availability is also an issue. High prices limit demand and limited demand results in higher prices.
- Train and license additional staff pesticide applicators to help improve the application of pesticides (including herbicides) in the field and provide better direction or guidance to applicators, even if the trained staff are not directly applying the pesticides. Establish agency and cross-agency teams that specialize in following and implementing IPM, to increase the effectiveness of herbicide applications and decrease the amount of herbicides applied to the landscape.
- Establish statewide best management practices (BMPs) for the monarch, which will benefit other pollinators as well.
- Implement BMPs for pollinators in restoration and maintenance.
- Assess practices employed on public lands that are in agricultural production, to identify further IPPM opportunities.

Colorado Parks & Wildlife

Existing Programs & Policies

Colorado Parks and Wildlife (CPW) is responsible for perpetuating the wildlife resources of the state, providing a high-quality state parks system, and providing enjoyable and sustainable outdoor recreation opportunities, while also serving as the active stewards of Colorado's natural resources. CPW is involved with several programs and policies that directly benefit pollinators—though they are not the primary focus—through habitat improvements, protecting large intact landscapes, and promoting biodiversity.

CPW considers Endangered Species Act-listed insect species, particularly when they occur on CPW properties or may be impacted by CPW action. CPW also funds and incorporates native seed mixes and other native habitats. For nearly 20 years, CPW has contributed financially to native plant development efforts led by the (now defunct) Uncompahgre Partnership. CPW is involved with ~8,000 acres of Natural Resources Conservation Service (NRCS) CP 42, pollinator habitat plantings across the state.

Corners for Conservation Program (C4C)

- **Description:** C4C is a partnership between Pheasants Forever, farmers, CPW, NRCS, High Plains Land Conservancy, and Muley Fanatics that incentivizes landowners to set aside and manage small portions of their land for wildlife. This program encourages the establishment of diverse mixtures of wildflowers and native grasses, and other pollinator-friendly plantings in previously cropped corners of center pivot agricultural fields or buffer areas around playa wetlands on agricultural land.
- **Benefits to Pollinators**: Provides high-quality pollinator habitat. Increases forage resources and nesting sites for bees, butterflies, and other pollinators.
- **Link:** www.coloradopf.com/corners-for-conservation-c4c

Seed Warehouse

- **Description:** Harvested seeds are stored in 25–50 lbs (11.3–22.6 kg) sacks on pallets to be used for restoring burned areas or enhancing habitat for various wildlife species such as the Gunnison sage-grouse.
- **Benefits to Pollinators**: Native seed can be used for pollinator habitat. Increases forage resources and nesting sites for bees, butterflies, and other pollinators.
- **Link:** www.fs.usda.gov/detail/gmug/home/?cid=STELPRDB5401096

Wetland Wildlife Conservation Program

- **Description:** WWCP is a voluntary, incentive-based program to protect wetlands and enhance wetland-dependent wildlife on public and private land.
- **Benefits to Pollinators**: Wetlands provide a rich diversity of native plants that serve as forage for pollinators, and their presence significantly contributes to the overall landscape's ecological health. Safeguarding these wetlands ensures pollinators have access to ample food sources, breeding sites, and protection from environmental threats, ultimately supporting and sustaining local pollinator populations in the state.
- **Link:** cpw.state.co.us/aboutus/Pages/Wetlands.aspx

Resource Stewardship Program (State Parks)

- **Description:** Focusing on state parks, teams take proactive monitoring and protective measures to be sure that economic and recreational endeavors balance with conservation efforts. With thoughtful placement of operational and recreational infrastructure, the highest quality habitats in a given location can be maintained while meeting the human-use goals of a given property. This statewide program provides leadership and direction to state parks in addressing all natural and cultural resource issues. Pollinators are a component of several focus areas:
    - » Implementation of Directive B-304: Providing guidance for development projects and ensuring consideration of imperiled species and high-quality habitats.
    - » Implementation and Support of Directive OP-6 Use of Native Vegetation on State Parks: These specifications include seed mixes that contain native plants that are known to exist in the park, known to be commercially available, and known to have success in revegetation

projects. These mixes are also designed with a mix of forbs and grasses, have higher revegetation success, and contain high levels of pollinator-friendly species.
    - Noxious weed inventory and planning—Implementation and Support of Directive OG-6 Invasive Species and Native Pests: Maps and monitors non-native or invasive plant species in state parks and creates integrated weed management plans specific to each park location. Plans are updated at a minimum every five years.
    - Resource Stewardship Plans: Identifies occurrences and habitat for SGCN and other species of conservation interest, and recommends approaches for species and habitat management.
    - iNaturalist community science biological inventory: Promoting this work since 2017 has generated 11,000 invertebrate observations in state parks.
    - Forest management: Planning and implementation of forestry projects focused on wildfire mitigation, forest health and wildlife habitat. Prescribed fire coordination and project planning. Forest management plans are created specific to each state park location.
    - Biological inventory with Colorado Natural Heritage Program (CNHP): Includes pollinators and rare or uncommon plants and plant communities.
    - In each state park, vegetation is mapped and includes a condition assessment so that the state park areas in the most native condition can be conserved and the areas in lower condition can be enhanced or restored.
- **Benefits to Pollinators**: Increases forage resources and nesting sites for bees, butterflies, and other pollinators. For each state park, a pollinator habitat specification and native seed mix has been created. These specifications were created using pollinator plants known to exist on the property and seed that is commercially available, with seed collection recommendations for plants that would be beneficial to have in a pollinator habitat in that specific location.
- **Link:** cpw.state.co.us/aboutus/Pages/ResourceStewardship.aspx

Private Land Program

- **Description:** The following private land programs provide incentives and/or assistance for landowners with an interest in enhancing wildlife habitat, managing wildlife impact, and specific conservation on private lands.
    - Habitat Partnership Program
    - Colorado Wildlife Habitat Program
    - Partners for Fish and Wildlife
    - Pheasant Habitat Improvement Program
    - Private Lands Wildlife Biologist Program
        - Pheasants Forever
        - Bird Conservancy of the Rockies
- **Benefits to Pollinators**: Promotes wildlife habitat and increases forage resources and nesting sites for bees, butterflies, and other pollinators.
- **Link:** cpw.state.co.us/aboutus/pages/privateland.aspx

Colorado Wildlife Habitat Program

- **Description:** The CWHP offers funding opportunities for landowners who wish to voluntarily protect important wildlife habitat, provide wildlife-related recreational access to the public, and, if appropriate, sell their property to CPW. Has approximately $10 million plus in annual funding for habitat protection.

- **Benefits to Pollinators**: Promotes wildlife habitat and increases habitat resources for bees, butterflies, and other pollinators.
- **Link:** cpw.state.co.us/aboutus/Pages/LandWaterCWHP.aspx

Colorado Seed Mix Tool Mobile App

- **Description:** This tool helps land managers build custom seed mixes for habitat creation or restoration projects. This calculator will include a pollinator habitat option. Working in partnership with the Habitat Partnership Program support. CDOT, other state agencies, and other land stewards will use this tool.
- **Benefits to Pollinators**: Each mix will include 5–7 grasses and 3–7 forbs for the project depending on area. Increases forage resources and nesting sites for bees, butterflies, and other pollinators.
- **Link:** play.google.com/store/apps/details?id=com.colorado_seed_app

Colorado State Wildlife Action Plan (SWAP)

- **Description:** The SWAP outlines which of Colorado's species and habitats are the most vulnerable and identifies species of greatest conservation need, threats, and conservation actions to address those threats. The SWAP is intended to be a resource for and to enhance state planning efforts. It supports cooperation, participation, and commitment among wildlife managers, landowners, private and public land managers, and other stakeholders in developing and implementing conservation actions.
- **Benefits to Pollinators**: Plan raises awareness and identifies conservation actions for wildlife species of greatest conservation need. The current SWAP includes a list of insects (including pollinators) and native plants of greatest conservation need in an appendix.
- **Link:** cpw.state.co.us/aboutus/pages/statewildlifeactionplan.aspx

Ranching for Wildlife Program

- **Description:** Through this program, hunters can play an important role in helping CPW and landowners manage wildlife populations on private land. In addition to providing public hunting access to successful applicants, participating landowners are required to improve habitat on their ranch for both game and nongame animals. Currently involves nearly 1 million acres of habitat improvements, wildlife management, and public access.
- **Benefits to Pollinators**: Program is primarily a hunter access program with a habitat component that is the landowners responsibility. Program can indirectly result in improvement of pollinator habitat.
- **Link:** cpw.state.co.us/thingstodo/Pages/RFW.aspx

Native Species Directive: Colorado Parks and Wildlife Administrative Directive No. OP-6 (2020)

- **Description:** This directive promotes the use of vegetation native to Colorado for park landscaping, reclamation, and restoration projects, when appropriate; to protect, maintain, restore, or enhance the full complement of Colorado's native ecosystems occurring within state parks and recreation areas; and to limit the use of non-native vegetation in state parks.
- **Benefits to Pollinators**: Increases native forage resources and nesting sites for bees, butterflies, and other pollinators.
- **Link:** n/a

Potential New Program and Policy Recommendations

Integrate pollinator conservation objectives and habitat requirements into CPW wildlife area management plans, state park management plans, and other habitat conservation and improvement programs and plans.

- **Description:** Integrate pollinator conservation objectives, habitat requirements, and land management practices as applicable into CPW programs and resource management plans that align with habitat conservation and improvement.
- Some example programs to consider include:
  - » Wetland Wildlife Conservation Program
  - » Colorado Wildlife Habitat Program
  - » Ranching for Wildlife Program
  - » Corners for Conservation Program (C4C)
- Some example land management plans include:
  - » State wildlife area management plans
  - » State park management plans
- **Staff Idea:** Yes
- **Rationale / Comments:** There are a number of existing CPW programs and management plans that have objectives and goals around providing wildlife conservation and habitat improvement and protection. Most of these plans and programs do not specifically call out native pollinator conservation or protection as explicit objectives or goals and identify strategies or actions that help to accomplish the conservation of pollinators. Many habitat-oriented objectives and actions typically align with pollinator conservation, however, so explicitly calling these out in plans and adding objectives and actions oriented to pollinators, their needs, and drivers of their decline, would ensure better attention to and results for pollinators and their habitats. It would be helpful to explore the benefits of these programs and plans for pollinators and then identify the gaps and existing needs.

Increase the capacity and staff support for the native Seed Warehouse and native plant supply programs.

- **Description:** CPW's Seed Warehouse provides a fundamental service through the storage of native seed, so that adequate supplies can be accumulated and made available for various CPW and partner habitat improvement projects. Increasing the funding, storage capacity, and support staffing is needed to meet current and future demand for native seed.
- **Staff Idea:** Yes
- **Rationale / Comments:** CPW's Seed Warehouse is important infrastructure to have as part of a program and chain of program elements that are needed to sustain and ideally increase native plant establishment programs and projects. The supply and cost of native plant materials was very commonly identified by staff as a barrier that limits the extent and success of native plant restoration projects. The Seed Warehouse is a successful facility and Western Slope service which should be expanded and enhanced by other connected statewide efforts to increase access to and the supply of native plant materials for state projects.

Add pollinator-related staff positions to support improved coordination and support for pollinator conservation and habitat improvements.

- **Description:** CPW does not have a staff position that provides expertise and is dedicated to or focusing on the conservation of native pollinator insects. Note: the following positions are not prioritized.
    - » Pollinator conservation specialist
    - » Pollinator partner biologists positions (similar to existing partner biologist positions with Bird Conservancy of the Rockies and Pheasants Forever, which do have some pollinator focus)
    - » Weed management/noxious weed coordinator
    - » Restoration ecologist
- **Staff Idea:** Yes
- **Rationale / Comments:** Creating and funding position(s) focused on bringing pollinator and invertebrate expertise and conservation experience to the agency will support the integration of pollinator conservation more fully into existing programs, and potential new programs and projects. Pollinator focused positions can also help support better coordination and collaboration across agencies and across the different state departments. The Pheasants Forever partner biologist positions have been key in securing USDA pollinator program CP-42 funds. The recommended positions were those that came out of recommendations from the survey and interviews with staff.

Evaluate and implement pollinator and pollinator habitat monitoring and survey programs.

- **Description:** Evaluate potential pollinator survey and monitoring programs and implement priority programs that address state information gaps about pollinators and their habitats, and provide information to guide management for the conservation of imperiled pollinators and SPGN. Additionally, develop pollinator monitoring protocols and practices that can be applied to CPW properties and projects. Protocols can be established to assess the status of pollinators or specific pollinator groups before and after projects are implemented and to conduct baseline pollinator surveys.
- **Staff Idea:** No
- **Rationale / Comments:** Gaps in having better information about the status of pollinators and their habitats in Colorado, understanding how pollinators respond to environmental changes, and how to integrate science into the practical applications of management actions, can be mitigated by implementing ongoing pollinator survey, monitoring, and studies targeted to address the most urgent information needs. The state staff survey included a question assessing if state agencies conduct any pollinator or pollinator habitat survey or monitoring. Survey results (yes, 24%; no, 44%; unsure, 32 %) are a good indication that there is a gap, and therefore, a need to assess what survey and monitoring objectives would be most important and then establish protocols and programs to accomplish the monitoring priorities.
    - » Example program: The Oregon Bee Project

Other Potential Opportunities & Concerns That Were Identified

- Move towards ecology-based (instead of species-specific) project design.
- Update as needed CPW Native Plant Revegetation for State Parks and integrate pollinator conservation practices, as appropriate.

- In development projects for roads, trails, buildings, etc., revegetation is typically wrapped into the overall construction contract and is the first thing to be pulled or significantly modified when there are cost overruns in the construction phase.
- See CDOT recommendation: Collaborate with CPW, CSFS, SLB, and other state agencies that purchase native seeds and plants and coordinate working with native plant growers and seed suppliers to align and leverage the state's purchasing power to improve the supply of native plant materials.
- Increase utilization of Colorado Conservation Data Explorer as a resource to provide information to decisions regarding grants, development, and habitat management.
- Continue promoting the benefits to pollinators achieved with the Corners for Conservation Program and look for opportunities to enhance pollinator and pollinator-habitat conservation objectives and purposes.
- Develop a map of high-value pollinator species; also see mapping recommendation in Policy and Program Recommendations for CDOT.
- Connectivity plan needs to integrate and incorporate pollinator awareness and conservation into current planning efforts.
- The Bee and Butterfly Habitat Fund has developed good material developing pollinator habitat on former cropland. The Society for Range Management has also explored increasing pollinators on rangelands through different grazing practices.
- There needs to be a focus on building and utilizing practitioner knowledge.
- Include pollinators in habitat plans being written by CPW staff.
- The NRCS Plant Materials Centers, when they were more adequately funded, were an excellent resource for state staff to collaborate with and benefit from shared knowledge and resources for native plant habitat establishment.

Colorado Natural Areas Program

Existing Programs & Policies

The Colorado Natural Areas Program (CNAP) is a statewide program managed by CPW that focuses on the recognition and protection of areas that contain at least one unique or high-quality natural feature of statewide significance.

State Natural Areas

- **Description:** CNAP works with interested landowners to designate state natural areas and protect sites that contain at least one unique or high-quality natural feature of statewide significance, which can include pollinator species. There are 96 designated state natural areas.
- **Benefits to Pollinators**: Increases forage resources and nesting sites for bees, butterflies, and other pollinators. Assists in the protection of significant natural communities, rare plant species, and pollinators and their habitat.
- **Link:** n/a

Rare/Native Plant Conservation

- **Description:** CNAP undertakes and supports targeted surveys to identify new populations of rare plants, the collection of quantitative data on rare plant population trends, and observational data collection on known rare plant occurrences.

- **Benefits to Pollinators**: Increases understanding of native forage resources and nesting sites available for bees, butterflies, and other pollinators.
- **Link:** cpw.state.co.us/aboutus/Pages/CNAP-Rare-Plants.aspx

Potential New Program & Policy Recommendations

Assess and update State Natural Area (SNA) designation guidance to include and prioritize lands important for native pollinator conservation and protection.

- **Description:** Assess existing guidance that supports the designation of SNAs for opportunities to better integrate and enhance the prioritization of lands with high native pollinator conservation values. Prioritize the designation of SNAs where imperiled pollinators or high-quality and diverse pollinator communities are known, and create criteria to help evaluate and prioritize sites with higher pollinator or invertebrate conservation needs.
- **Staff Idea:** No
- **Rationale / Comments:** CNAP supports the conservation of unique state resources. Ensuring that the information about lands being considered for potential designation include information about pollinator habitat qualities and any pollinator species of greatest conservation need would help to prioritize and ensure that SNA designations include important pollinator habitats.

Include observations of pollinator and floral associations into plant surveying efforts.

- **Description:** Develop the capacity, tools, and practices to observe and document pollinator and floral-association information into plant surveys and monitoring projects.
- **Staff Idea:** Yes
- **Rationale / Comments:** Increasing what's known about the floral associations of native pollinators with native plants can provide valuable information to guide pollinator habitat restoration and creation. Integrating this information into CNAP's ongoing plant survey and monitoring efforts would benefit this information for SNAs and for pollinator conservation more broadly in Colorado.

Other Potential Opportunities & Concerns That Were Identified

- Update the Native Plant Revegetation Guide for Colorado as needed and integrate pollinator habitat considerations and conservation management practices as appropriate. Update and widely distribute.

Colorado State Forest Service

Existing Programs & Policies

The Colorado State Forest Service (CSFS) is involved with a few programs that are directly dedicated to the protection and enhancement of pollinators. These initiatives are primarily in collaboration with the community science and extension efforts of CSU. In addition to the programs and policies outlined below, CSFS has publicly distributed information about agroforestry and how to incorporate tree plantings that will benefit pollinators. CSFS provides technical forestry assistance, wildfire-mitigation expertise, and outreach and education to help landowners and communities. Considering the importance of forests for native pollinator populations, the formal introduction of pollinator-specific programs and policies into CSFS plans could be highly beneficial.

Forest Action Plan

- **Description:** An in-depth analysis of forest trends offers solutions and guidance for improving forest health and ensuring our forests—and the resources they provide—persevere for future generations. Helps direct activities to maintain habitat for wildlife, clean air, clean water, and carbon sequestration to mitigate climate change
- **Benefits to Pollinators**: Uses data-based decisions to maintain high-quality wildlife habitat. Can indirectly promote pollinator habitat. Increases forage resources and nesting sites for bees, butterflies, and other pollinators.
- **Link:** csfs.colostate.edu/forest-action-plan/

Forest Management Best Management Practices

- **Description:** The US Forest Service currently has 99 forest management practices documented, 96 of which are certified and approved as BMPs. The three remaining practices are still being improved before referral to the State and EPA for certification and approval. CSFS uses and refers to the US Forest Service BMPs to provide information and consultation on forest management practices. Work continues on developing new management practices and evaluating the effectiveness of the existing BMPs.
- **Benefits to Pollinators**: Promotes high-quality wildlife habitat and supports reducing pesticide usage. Increases forage resources and nesting sites for bees, butterflies, and other pollinators.
- **Link:** www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsm9_027608.pdf

CSFS Seedling Tree Nursery

- **Description:** This 130-acre nursery produces seedlings of more than 40 species of low-cost, Colorado-grown trees and shrubs for conservation purposes. Nursery staff continuously conduct trials to identify new species that will address landowner needs.
- **Benefits to Pollinators**: Provides plant materials that may support pollinator foraging.
- **Link:** csfs.colostate.edu/seedling-tree-nursery/

Potential New Program & Policy Recommendations

Assess further opportunities and continue to pursue efforts to update and expand the capacity of the state nursery in Fort Collins and regional nurseries to propagate a greater number and diversity of native plants.

- **Description:** The state nursery is an important resource for providing native plants for state projects as well as the general public. There is a need to expand the capacity of the main and regional facilities for propagating more plants and a greater diversity of native plants to serve an increasing demand for native plants. In addition to plant propagation, adding native seed collection, processing, and supply would further extend the service the nursery could provide to support native plant habitat restoration and creation.
- **Staff Idea:** Yes
- **Rationale / Comments:** The state nursery has recently received funding to support facility updates which were badly needed. Continued assessment of infrastructure improvements needed along

with opportunities to increase the capacity and expand the range of native plant materials provided is a key component of a state integrated effort to expand the use of native plants for pollinators and build both in-state and external capacity for native plant and seed supplies. There are many potential Colorado-based organizations that have extensive expertise in native seed propagation and collection that can be collaborators in this effort.

Enhance information available about managing forests and trees to conserve native pollinators.

- **Description:** Collaborate with CSU extension and other expertise available through CSU along with local researchers and organizations to create information for the public about managing forests with pollinators in mind. Consider providing fact sheets, practice recommendations, and general information on the agency website.
- **Staff Idea:** No
- **Rationale / Comments:** CSFS provides excellent and extensive information to Colorado residents about healthy forest management and wildfire mitigation and preparedness. Between people seeking information from CSFS and the agency's education and outreach capacity, there is a great opportunity to expand information about native pollinators and land management for pollinators.

Develop forest management prescription goals, objectives, and practices for native pollinator habitat management that can be integrated into forest plans and prescriptions CSFS provides.

- **Description:** Create templates for pollinator conservation and habitat restoration goals, objectives, and recommended practices to integrate into forest planning documents prepared by CSFS staff. Use information available in this study and other available research and information to develop templates.
- **Staff Idea:** No
- **Rationale / Comments:** CSFS provides expertise to develop planning documents for state forests and other lands, and through collaborations with other partners. Integrating the best available information into draft templates for planning goals, objectives, and land management practices will support the integration of pollinator-related components into forest plans and other planning documents and will result in improved conditions for pollinators.

Other Potential Opportunities & Concerns That Were Identified

- Collaborate with CPW, CSFS, SLB, and other state agencies that purchase native seeds and plants and coordinate working with native plant growers and seed suppliers to align and leverage the state's purchasing influence to improve the supply of native plant materials. Also see seed supply recommendation in Policy and Program Recommendations for CDOT.

State Board of Land Commissioners

Existing Programs & Policies

The State Board of Land Commissioners (SLB) is putting more emphasis on stewardship of their lands (as opposed to primarily financial value), which is of benefit to pollinator habitat. They are focused on maintaining and improving functional rangelands. Grazing management education fosters high-quality habitat management and encourages the growth of a large range of pollinator forage species. They are working on increasing "pollinator plots" (areas of old farmland or tilled ground that are planted with pollinator-friendly plants) on managed lands. There are new initiatives for supporting holistic and regenerative grazing practices on state trust lands. There are also new lease stipulations for land restoration (such as using native seeds) and protecting wetlands and riparian areas.

There is agency funding to directly support pollinator habitat restoration projects: approximately $20,000 per year for the SLB Ecosystem Services program. This funding has been used for related projects due to insufficient staff resources for pollinator projects. Ultimately pollinator conservation fits within the urban forestry and sustainability goals of SLB. Rare plants and pollinators are considered in SLB reclamation projects (BIOTICS).

Stewardship Action Plan (SAP)

- **Description:** An SAP is an adaptive management plan (prepared by staff) that describes SLP's comprehensive vision, objectives, strategies, and best management practices for responsible stewardship of a particularly important target plant or animal species occurring at a landscape scale on numerous, noncontiguous state trust lands. The Greater Sage Grouse SAP was adopted in 2016 and re-approved in 2021, and the Lesser Prairie Chicken SAP and Fen SAP were adopted in 2020. Further SAPs are planned for, Gunnison sage-grouse, rare plants, and wetlands.
- **Benefits to Pollinators**: Increases native forage resources and nesting sites for bees, butterflies, and other pollinators.
- **Link:** slb.colorado.gov/stewardship-action-plans

Business Program Reviews

- **Description:** SLB staff review potential impacts from proposed leases on state trust lands involving oil and gas, solid minerals (mining), renewable energy, and other development, and recommend stewardship related lease stipulations that protect identified natural resources, wildlife habitat, or rare plants. Staff uses the following resources to identify species and recommend BMPs for their protection:
    - » Colorado Natural Heritage Program NatureServe BIOTICS database
    - » CPW High-Priority Habitat maps
    - » CPW Species Activity Maps
    - » CPW State Wildlife Action Plan (tier 1 and 2 species)
- **Benefits to Pollinators**: Appropriate timing or spatial stipulations or BMPs could be developed to protect rare pollinators. If CPW developed a species activity map (SAM) GIS layer for pollinators this could be useful for knowing where to apply these BMPs.
- **Link:** n/a

Stewardship Trust Management Plans and Asset Management Plans

- **Description:** Property-specific management plans that identify natural values and recommended practices for their management, enhancement, or protection. Properties range from 100 to 180,000 acres (40 to 72,840 ha) in size.
- **Benefits to Pollinators**: Appropriate pollinator BMPs could be added to management plans for properties where rare pollinators have been identified.
- **Link:** n/a

Potential New Program & Policy Recommendations

Create a Pollinator Stewardship Action Plan (SAP)

- **Description:** Collaborate with CPW staff and other pollinator experts to identify the highest conservation value pollinator-related practices that would be suitable for SLB properties. Once identified, collaborate with CPW and other partner organizations to develop the SAP.
- **Staff Idea:** No
- **Rationale / Comments:** SAPs are used by SLB to guide and influence the conservation of important natural resources occurring on SLB lands. Going through a collaborative process with pollinator experts to assess potential pollinator-related SAPs and developing a SAP for the SLB properties with the greatest value for pollinators would be an important tool to increase pollinator conservation on these widespread and numerous state lands.

Add or improve requirements or incentives into leases for conservation practices.

- **Description:** Assess existing and integrate additional pollinator conservation requirements and incentives for competitive or RFPs for leasing opportunities of SLB properties.
- **Staff Idea:** No
- **Rationale / Comments:** Most SLB properties have lessees that are responsible for land management activities prescribed by a property lease. Enhancing existing conservation requirements and integrating additional incentives or preferences for awarding leases to operators that will implement land-management practices consistent with pollinator conservation (e.g., IPM practices and reducing pesticides) will improve the management of SLB properties for pollinators.

Add or improve requirements or incentives into leases for conservation practices.

- **Description:** Assess existing and integrate additional pollinator conservation requirements and incentives for competitive or RFPs for leasing opportunities of SLB properties.
- **Staff Idea:** No
- **Rationale / Comments:** Most SLB properties have lessees that are responsible for land management activities prescribed by a property lease. Enhancing existing conservation requirements and integrating additional incentives or preferences for awarding leases to operators that will implement land-management practices consistent with pollinator conservation (e.g., IPM practices and reducing pesticides) will improve the management of SLB properties for pollinators.

Develop a Pollinator Habitat Enhancement Program.

- **Description:** Create pollinator habitat enhancement pilot projects on state trust lands that can be used to sell credits on the emerging voluntary biodiversity market. This could be achieved on small areas of unleased state lands, sites degraded from surface development, and O&G pads.
- **Staff Idea:** Yes

- **Rationale / Comments:** Once successful pilot projects are completed, request SLB funding to expand this program.

Grassland carbon and regenerative grazing leases

- **Description:** Integrate pollinator habitat enhancement into regenerative grazing and grassland carbon sequestration leases.
- **Staff Idea:** Yes
- **Rationale / Comments:** Grassland carbon sequestration projects generally involve regenerative grazing practices, which support plant vigor, health, and structural diversity of rangeland forbs and grasses. These projects are likely to increase native forage resources and nesting sites for bees, butterflies, and other pollinators.

Pollinator seed mixes

- **Description:** Require pollinator-friendly native seed mixes for revegetating state trust lands impacted by surface development, such as rights-of-way, O&G, renewable energy, and mining.
- **Staff Idea:** Yes
- **Rationale / Comments:** Increases native forage resources and nesting sites for bees, butterflies, and other pollinators.

Other Potential Opportunities & Concerns That Were Identified

- Integrate conservation practices and IPM practices (including using alternatives to herbicides) into cost-support incentives for weed management.

3.3.4. Colorado Department of Agriculture

Existing Programs & Policies

The Colorado Department of Agriculture (CDA) has a broad scope of responsibilities that potentially relate to pollinator conservation. This includes a few programs and policies specifically dedicated to the protection and enhancement of managed pollinators. The regulation and certification requirements of pesticides is another area of overlap. Additionally, programs related to supporting diversified agricultural practices, regenerative farming practices, and soil health are also important. Perhaps most significant is the role for educating and guiding the management and control of invasive plants and pests. These programs span a diverse range of efforts from habitat restoration and pesticide management to educational opportunities.

Colorado Managed Pollinator Protection Plan (MP3) Guidelines

- **Description:** Guiding document of BMPs to avoid and prevent impacts on pollinators. Reviewed by the Colorado Department of Agriculture Pesticide Advisory Committee.
- **Benefits to Pollinators**: Encourages use of IPM, planting pollinator forage, BMPs for managed pollinators, and communication between beekeepers and pesticide applicators.
- **Link:** ag.colorado.gov/plants/apiary-program-page/pollinator-protection

DriftWatch - Pesticide Sensitive Viewer

- **Description:** Allows pesticide applicators, specialty crop growers, and stewards of at-risk habitats to communicate more effectively to protect pesticide-sensitive areas.
- **Benefits to Pollinators**: Mitigates exposure of pollinators to harmful pesticides and encourages communication about pesticide application and pollinator habitat.
- **Link:** ag.colorado.gov/driftwatch-pesticide-sensitive-viewer

Saving Tomorrow's Agricultural Resources (STAR) Soil Health Program

- **Description:** STAR Soil Health Program evaluates 11 different cropping systems and grazing lands for soil health.
- **Benefits to Pollinators**: Supports soil health and nesting habitat for pollinators.
- **Link:** https://ag.colorado.gov/soil-health

Pest Control Districts

- **Description:** Pest control districts are organizations within a contiguous territory, formed under the general supervision of boards of county commissioners, for the control and eradication of noxious weeds, insect pests, or plant diseases injurious to agricultural crops, trees, fruits, or pasture. Pest control districts may be established to control specific pests. Examples include mosquito control districts, grasshopper control districts, and weed control districts.
- **Benefits to Pollinators**: Can encourage communication about the relationships between pesticide application and pollinator habitat. Districts also have the ability to evaluate and mitigate risks associated with their management practices.
- **Link:** https://webdoc.agsci.colostate.edu/cepep/FactSheets/410PestControlDistricts.pdf

Pesticide Applicator Certification and Licensing Program

- **Description:** Promotes the safe and effective use of pesticides and certain devices to control pests such as insects, rodents, and weeds
- **Benefits to Pollinators**: Trains applicators to mitigate exposure of pollinators to harmful pesticides and encourages communication about pesticide application and pollinator habitat.
- **Link:** ag.colorado.gov/plants/pesticides/pesticide-applicator-certification-and-licensing-program

CDA prioritizes the reduction of pesticide usage by researching and advocating for the use of effective biological control (e.g., Request-a-Bug Program) in pest management. The enforcement of pesticide labeling requirements helps avoid unreasonable adverse effects posed by pesticide use. Soil health, noxious and invasive weeds, and biocontrol are all considered in management decisions. Continuing education credits are available for licensed pesticide applicators through training on pollinator protection.

Potential New Program & Policy Recommendations

Assess managed honey bee (apiary) registration, license, or inspection programs occurring in other states to determine potential models that would be sustainable for the state to adopt and implement.

- **Description:** Conduct an assessment of states with managed honey bee registration, license, or inspection programs that could be feasible, effective, and financially viable models for Colorado. Develop a suitable strategy and proposal for Colorado that offers benefits and services to beekeepers

and considers protections for native bees and other pollinators, without the full cost of the program to be the responsibility of the beekeepers.
- **Staff Idea:** Yes
- **Rationale / Comments:** Registration, licensing, or inspection of commercial honey bee hives or hobby (backyard) hives in Colorado is not required by the state. Colorado's previous commercial apiary registration program ended in 1990 due to the program costs being funded by beekeepers and lack of interest in being regulated. The commercial apiary inspection program was paid for through inspection fees. The program helped fund and track the number of commercial beekeepers and hive health conditions. The program also provided education resources and support resources to assist with identifying and treating honey bee diseases, parasites, and other hive-health hazards such as pesticide exposures. Existing inspections of apiaries are only conducted at the request of a beekeeper to meet export certification required by another state. The beekeeper is responsible for all costs associated with a requested inspection. The benefits of the state administering a managed honey bee hive program include tracking the statewide numbers, locations, and health of hives, while also providing information and services to support the maintenance of healthy hives and guidance to beekeepers on how support native bees and pollinators and reduce risks to them associated with managed pollinators.
- Example state programs to possibly consider:
    - » North Dakota
    - » Iowa's Apiary Registry
    - » Michigan's voluntary system
    - » New York

Work with municipalities and other local governments to provide information to noncommercial (hobby) beekeepers about healthy hive management and native bee (pollinator) conservation.
- **Description:** Explore opportunities and approaches to collaborate with municipalities and other local governments to align key educational messages and related content intended for noncommercial (hobby) beekeepers about healthy hive management practices, providing adequate forage for hives, best practices for locating hives, among other topics to minimize impacts of managed hives on native bees and other pollinators.
- **Staff Idea:** No
- **Rationale / Comments:** Conservation concerns for native bees and impacts from managed honey bees has resulted in some local governments and counties (e.g. Adams County and the cities of Centennial and Parker) establishing policies or even requiring permits for hives. Other local governments may provide only information or not address this topic at all. The state serves an important role through offering information, best practices, and appropriate policy guidance to local governments. Through providing information on the department's website and using outreach and established relationships with local governments, CDA can provide leadership and promote hive-management practices that encourage native pollinator conservation.
    - » Helpful resource: Why Getting a Hive Won't "Save the Bees"

Collaborate with state agencies that apply pesticides to require that all staff that are applicators, should regularly participate or attend state-approved commercial applicator training courses.
- **Description:** CDA has oversight for pesticide continuing education courses for private applicators, registered limited commercial, registered public applicators, and commercial pesticide applicators. Exploring approaches that require or encourage state staff and contractors that are licensed

commercial pesticide applicators to participate in these training opportunities could leverage the benefits of these training for state staff.

- **Staff Idea:** Yes
- **Rationale / Comments:** CDA approves over one hundred pesticide continuing education courses annually which creates training opportunities for building awareness of best practices around IPM principles, recommended pesticide application practices, and mitigating risks to pollinators. Requiring that all state applicators regularly attend state-approved commercial applicator training courses, whether they or their staff are licensed as a commercial pesticide applicator, could build staff awareness and consistency in using recommended practices.

Provide additional information and resources about conserving and protecting native bees and pollinators on the department's Pollinator Protection webpage.

- **Description:** CDA has a web page with information about the protection of pollinators including managed bees and native insect pollinators. Information from this study, referred resources, and information available by the CSU Extension, state universities and pollinator conservation organizations like the Xerces Society, the Butterfly Pavilion, and People and Pollinators Action Network, can all be helpful resources to inform conservation actions and information that can be shared on the website.
- **Staff Idea:** No
- **Rationale / Comments:** The state serves an important role in connecting the public with information to help inform and guide actions that they can take to help protect the health of native pollinators. Providing information about both managed and native pollinators, the pollinator protection web page can be an important resource and asset for the state to disseminate information to individuals seeking information generally or specifically about protecting pollinators.

Update the Draft Colorado Managed Pollinator Protection Plan (MP3) Guidelines to integrate additional guidance relative to native pollinating insects.

- **Description:** Consult with native pollinator experts and stakeholders to identify opportunities where additional information, science, and guidance can be integrated into the draft plan.
- **Staff Idea:** No
- **Rationale / Comments:** The Draft Colorado Managed Pollinator Protection Plan (MP3) Guidelines provide guidance about general practices to avoid and prevent impacts to Colorado pollinators. The guidance and recommendations are primarily focused around managed bees (honey bees), but the plan does include some information relevant to native bees and other pollinators. As a plan that offers guidance to the public about the protection of managed pollinators, it also can serve a purpose to build awareness around the common risks and threats affecting managed and native pollinators and actions that can serve to avoid or mitigate risks.

Establish a biennial meeting for state weed managers and specialists to share information.

- **Description:** Coordinate a biennial meeting of state weed managers and specialists to share information about invasive weed integrated management strategies, management practices, adaptive management results, and new invasive plants that could present management and ecological challenges. Meetings could also provide learning opportunities about current pollinator-related concerns and recommendations.
- **Staff Idea:** No
- **Rationale / Comments:** State departments, including CDOT, CDA, CPW, SLB, and CSFS—and

likely others—have weed management operations, responsibilities, and staff expertise. Establishing opportunities where the state weed experts, managers, and technicians share information, identify ways to leverage resources, collaborate to solve challenges, and keep current on the latest information will help to address the ongoing challenges of managing invasive plants. These information sharing sessions could also be helpful in highlighting opportunities to reduce the use of pesticides and consider opportunities to support native pollinators.

Integrate pollinator conservation practices into the content and standards for pesticide applicator license requirements.

- **Description:** Look for opportunities to integrate into the pesticide applicator license required training standards information and practices relevant to the conservation of pollinators and avoiding or reducing risks to pollinators. The training could include topics and practices relating the importance of native insect pollinators, risks from pesticides, and recommended practices to reduce risks to pollinators.
- **Staff Idea:** No
- **Rationale / Comments:** Embedding information and standards into training about pollinator conservation concerns, pesticide risks to pollinators, and recommended practices that reduce or avoid harm to pollinators will encourage licensed applicators to consider and apply recommended practices.

Assess overarching practices by the state's pest control districts to determine if a deeper review is warranted to improve native pollinator conservation efforts.

- **Description:** The state has specific rules (8-CCR 1203-7) stipulating how counties can organize and implement pest control through districts. A broad assessment of the overarching practices would help to identify if a more detailed and thorough review would be warranted to identify opportunities where pollinator conservation recommended practices and threats could be more consistently integrated and addressed.
- **Staff Idea:** No
- **Rationale / Comments:** Districts often have special provisions or protections for honey bees, which are important and helpful and may also help native pollinators. However, many native pollinators cannot be protected from pesticides in the same ways that managed honey bees can be (i.e., removing or covering the hive). An assessment of practices, guidelines, and provisions that the different pest control districts have, would help identify opportunities where the state could consider stronger guidance to support protections for native pollinators. These reviews could supplement information provided in this study and inform more specific management recommendations that could be provided to the districts.

Explore opportunities to integrate pollinator-related objectives and pesticide-mitigation practices into IPM training and outreach information.

- **Description:** Look for opportunities to overlay pesticide-risk reduction practices for pollinators in existing training and programming. Coordinate with partners such as CSU Extension on strategies to combine pollinator practices into existing IPM programs.
- **Staff Idea:** No
- **Rationale / Comments:** Land managers, farmers, and ranchers face complex pest pressures. There is increasing research and information emerging about approaches to integrate pollinator-focused practices more directly into IPM programs, thus becoming IPPM programs. Evaluating IPPM

program practices and integrating relevant components into the existing state IPM training and outreach information would continue to promote IPPM approaches and potentially add more tools and pesticide mitigation measures for pollinators. CSU Extension could be a potential resource for assisting with information and assessment of opportunities.

Other Potential Opportunities & Concerns That Were Identified

- Evaluate the current state or number of commercial bumble bee colonies to inform if establishing state authority to regulate or restrict importation would be beneficial.
- Include consideration of native pollinator needs and issues if a future Colorado Pollinator Workgroup is convened.
- Consider if there are opportunities to integrate native pollinator habitat and conservation practices into the Saving Tomorrow's Agricultural Resources (STAR), Soil Health Program.
- Consider development of additional voluntary BMPs for neonicotinoids and other high-risk pesticides for pollinators, like those developed by the Minnesota Department of Agriculture.

3.3.5. Public Safety

Habitat Restoration and maintenance is a large part of prescribed fire. Healthy ecosystems are the overall goal of this type of land management.

Colorado Division of Fire Prevention and Control (DFPC)

Existing Programs & Policies

The Colorado Division of Fire Prevention and Control currently does not have any policy or funding in regard to pollinators. The primary goal of the DFPC is public safety. There may be room to consider pollinator conservation in future habitat management for fire risk mitigation.

Potential New Program & Policy Recommendations

Include pollinator conservation strategies and practices into prescribed burn plans and operations.

- **Description:** Assess with resource managers opportunities to develop and integrate pollinator conservation objects into the resource management goals and objectives informing prescribed fire planning. Additionally, integrate pollinator conservation practices from this study and other best available information into prescribed fire plans to inform fire management operations that will help achieve objectives.
- **Staff Idea:** Yes
- **Rationale / Comments:** Prescribed fires can have a range of benefits and potential impacts to pollinator communities and their habitats. Prescribed burn plans are informed and guided by the management objectives identified by the land manager. Making sure that pollinator management

goals are identified and incorporated into prescribed fire planning will help to align how this land management tool can benefit pollinators while mitigating potential risks to their conservation.

Other Potential Opportunities & Concerns That Were Identified

- Incorporate pollinator conservation and ecology, pollinator habitat attributes, and native plant community information into training (could be incorporated into the first two weeks of training or annual fire workshop).

3.3.6. State Policies & Programs that Guide Pollinator Conservation

Existing Programs & Policies

There are no pollinator specific statewide programs or policies that focus on native pollinators. From 2017–2023, Governor Hickenlooper originally and now Governor Polis, have signed proclamations recognizing the month of June as Pollinator Month. While primarily an outreach and awareness campaign, this proclamation does help to encourage and support other pollinator awareness programs across the state.

Greening Government Executive Order D2023 18 and Greening Government Executive Order D 2022 016

- **Description:** The State of Colorado has a long-standing commitment to efficient and sustainable government operations. The State has made tremendous efforts through past executive orders towards a "greening government." The 2023 Executive Order D 2023 018 establishes several new goals and directives building from prior greening government executive orders. The actions benefiting pollinators more directly include:
  - » Develop and implement policy containing low-use/water-efficient landscape criteria for new development and significant redevelopment projects for state facilities that offer "ecoregion appropriate landscaping, including native or drought tolerant lawn grasses."
  - » Energy and water efficiency.
  - » Enhancing environmentally preferred purchasing opportunities.
- **Benefits to Pollinators**: The development of ecoregion-appropriate landscaping with native grasses will increase habitat resources for pollinators, especially if other native plants are integrated.
- **Links:** www.codot.gov/programs/environmental/Sustainability

Potential New Program & Policy Recommendations

Establish a statewide policy or directive to prioritize the use of native plants.

- **Description:** Establish a state directive or policy similar to CDOT's "Landscaping with Colorado Native Plant Species" Procedural Directive 503.1 and Department of Natural Resources,CPW Administrative Directive OP-6, Use of Native Vegetation 2020.
- **Staff Idea:** Yes
- **Rationale / Comments:** With one department in the state (CDOT) already having a native plant directive in place and other state agencies also having either directives or interests in increasing

the use of native plants, a statewide approach would provide more consistency and weight to the importance of this action. Using native plants not only helps pollinators and other wildlife, but aligns with climate-resilient practices and the Greening Government executive orders. A statewide approach will also increase demand for native plants and help to influence and support growers and suppliers to increase their supply and diversity of native plant and seed stock.

Consider a future executive order or directive recommending that all state land management agencies have integrated pest or vegetation management plans (IPM/IPPM/IVM).

- **Description:** Consider a future executive order or directive recommending that state land management agencies that don't currently have integrated pest or vegetation management plans (IPM/IPPM/IVM) should establish plans and guidance with a goal of avoiding or limiting the use of pesticides and mitigating risks to nontarget species. The order or directive could also include establishing some fundamental objectives and criteria that all state IPM/IPPM/IVM plans should contain.
- **Staff Idea:** Yes
- **Rationale / Comments:** The importance of all state land managing agencies having IPM or IVM plans (ideally, IPPM plans) is to address and prevent pest/invasive vegetation problems, while minimizing risks to people, pollinators, and the environment. An IPM or IVM framework involves preventing conditions that favor pests or invasive vegetation and establishing thresholds at which pest management actions should be taken to avoid economic loss or a particular level of damage. Monitoring for pests or invasive vegetation, evaluating possible options, prioritizing the least-hazardous methods, and taking targeted pest management when management is warranted, are important process steps of a plan.

3.4. Federal Programs Supporting Pollinator Conservation

3.4.1. Summary of Existing Federal Programs & Policies Supporting Pollinator Conservation in Colorado

This is a non-comprehensive list of federal pollinator conservation guidance documents and programs that are relevant to the state of Colorado.

National Pollinator Health Strategy
National effort to promote the health of honey bees and other pollinators. This strategy aims to restore honey bee colony health to sustainable levels by 2025, increase Eastern monarch butterfly populations to 225 million by 2020, and restore or enhance seven million acres of land for pollinators. Additionally, this program is protecting pollinators from pesticide exposure.

Pollinator-Friendly Best Management Practices For Federal Lands
This document includes general information about practices and procedures to use when considering pollinator needs in project development and management of federal lands.

Department of Transportation (USDOT) & Federal Highway Administration (FHWA)

The USDOT provides opportunities to evaluate and increase pollinator habitat along roadways, and to work with state departments of transportation and transportation associations to promote pollinator-friendly practices and corridors. FHWA's approach to implementing this is to continue to support native plantings and integrated vegetation management (IVM) practices to reduce pesticide use and mowing, and increase native plantings. FHWA's Ecosystems and Vegetation Management toolkit has a section on pollinators that includes a literature review, a set of best management practices for practitioners (as well as a set for decision-managers), an interview report, case studies, and summaries of funding eligibility and legislation.

Bureau of Land Management (BLM)

The BLM provides a minimum of $20k a year for selected pollinator-focused projects, though this is typically only a fraction of the conservation work that can apply to pollinators. Other projects include:

- **Mountain States Bumble Bee Atlas:** This atlas will span across Colorado, Wyoming, Utah, and Idaho.
- **San Luis Valley Pollinator Surveys:** This project has been running since 2022, with observations being posted to iNaturalist. In 2024, the AIM Pollinator Supplementary Indicator will be used.
- **Rocky Mountain Butterfly Consortium (Butterfly Pavilion):** The Butterfly Pavilion will identify diurnal pollinators and other invertebrates, including species targeted for conservation such as monarch butterflies and western bumble bees. Complete representative surveys are planned in each of the following vegetative communities: shrublands, wetlands, sagebrush valleys, deserts, canyonlands, sagebrush steppe, and prairies and other grasslands. Flowering plants visited by invertebrates will be identified to create a database of feeding preferences for pollinators on BLM-managed lands.
- **Research:** BLM will partner with universities and other organizations to fund research relevant to pollinators. For example, in 2023, BLM partnered with CSU to work in McInnis Canyon and Dominguez-Escalante national conservation areas.

United States Department of Agriculture (USDA)

- Natural Resources Conservation Service (NRCS)**:** NRCS offers a range of conservation programs, such as the Environmental Quality Incentives Program and the Conservation Stewardship Program, which provide financial and technical assistance to landowners and agricultural producers. NRCS Pollinator Conservation Farm Bill Programs (2018-2023) summarizes existing pollinator conservation guidance, programs, and practices, and includes information on technical guidance documents, tools, and other resources available to support conservation planning for pollinators.
    - » NRCS Environmental Quality Incentives Program: EQIP helps farmers, ranchers, and forest landowners integrate conservation into working lands. Ten percent of EQIP funds are required to be used for wildlife projects, which include pollinator conservation projects.
    - » Conservation Stewardship Program: CSP offers technical and financial assistance to help agricultural and forest producers take their conservation efforts to the next level. The

program is designed to compensate agricultural and forest producers who increase their level of conservation by adopting additional conservation activities, such as the planting habitat for monarch butterflies.

- **USDA National Organic Program:** Products sold as organic in the United States must be certified under NOP by a USDA-accredited certification agency. The Colorado Department of Agriculture is an accredited agency that certifies producers and processors in the state of Colorado. CDA verifies that the requirements of organic production and handling practices meet the national standards. Food and other agricultural products that have been produced following NOP regulations carry the Organic label and may also display the USDA Organic seal.
- **Farm Service Agency (FSA):** With technical support from NRCS, FSA implements the Conservation Reserve Program. CRP provides valuable financial and technical assistance to growers for implementation of conservation practices that enhance pollinator habitat (such as the Pollinator Habitat Initiative CP-42). With yearly payments, CRP helps producers and landowners protect natural resources by establishing land cover, improving water quality, and increasing wildlife habitat.

General Services Administration

- **Pollinator Protection Initiative:** This GSA initiative is based on the Presidential Memorandum, ***Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators***, which established an inter-agency Pollinator Health Task Force, of which GSA was a member, to develop a national strategy to promote the health of bees, butterflies, other pollinating insects, birds, and bats.

Environmental Protection Agency

- **EPA Pollinator Protection:** EPA includes risk management within pesticide oversight with a focus on managed pollinators. It also conducts pesticide risk assessments to avoid unreasonable adverse effects on the environment including pollinators.

National Park Service

The NPS are four national parks (Rocky Mountain, Black Canyon of the Gunnison, Mesa Verde, Great Sand Dunes) and several national monuments in Colorado. Typical management strategies used by NPS (such as promoting native plant species, reduced mowing, and infrequent pesticide usage) frequently support pollinators in these locations. Additionally, the NPS has a website dedicated to pollinator information that promotes visitors to participate in the Pollinator Tracker Project via iNaturalist.

Photo: Xerces Society / Katie Lamke

Section 4.
Future Priorities for Pollinating Insect Health & Management

Using this study, which was asked for by the legislature, Colorado has a unique opportunity to develop goals that will support the health of pollinators and thus support natural and agricultural ecosystems across the state. The Scientific Review of Colorado Native Pollinating Insects presented in Section 2 of this study represents a distillation of the current research on the mechanisms impacting native pollinating insects, informed by research within the state and contextualized by relevant research from around the world. Similarly, the Conservation Practices for Pollinating Insects and Their Habitats in Section 3 of this study reflect the current state of scientific understanding, as well as a synthesis of priorities, best practices, and recommendations from state staff land managers, and drawing upon experts from across the country.

In response to the many different threats to Colorado's pollinators, the State will need to prioritize future actions based on impact and efficiency. In order to prioritize management practices, the State of Colorado should develop focused policy, actions, and guidelines targeting areas of highest need, such as conservation of the most imperiled species or habitats, and work to better understand our biggest gaps in management or policy. Moreover, policy solutions developed to have the most impact across different mechanisms driving native pollinator health, or to apply broadly across different state agencies, will allow for the most successful implementation of recommendations and actions focused on pollinators. For example, statewide policies that provide authority and directives, or fund positions to conserve pollinators, would maximize impact, while broadly applied recommendations, like reducing pesticide use or landscaping with native plants, could be adopted by multiple agencies simultaneously. To increase efficiency, state agencies and programs should promote applied and collaborative research that builds upon the resources and expertise within agencies, but also within collaborating research organizations, other levels of government, and non-governmental organizations. To maximize impact and minimize development time, actions should start with the most easily implemented conservation strategies. Collaborations among experts who understand the most important mechanisms driving pollinator communities, as well as with those who understand what strategies can be most successfully implemented in Colorado's landscapes, would result in impactful, efficient policy and management recommendations.

The creation of overarching guidance from both the executive and legislative branches and from agency leadership could be one of the biggest tools to increase access to information about and the adoption of management practices that best support the health and diversity of our native pollinating insects. Below, we discuss these needs, provide priorities for pollinator health, and discuss actions that the State can pursue to promote more healthy pollinating insects and habitats.

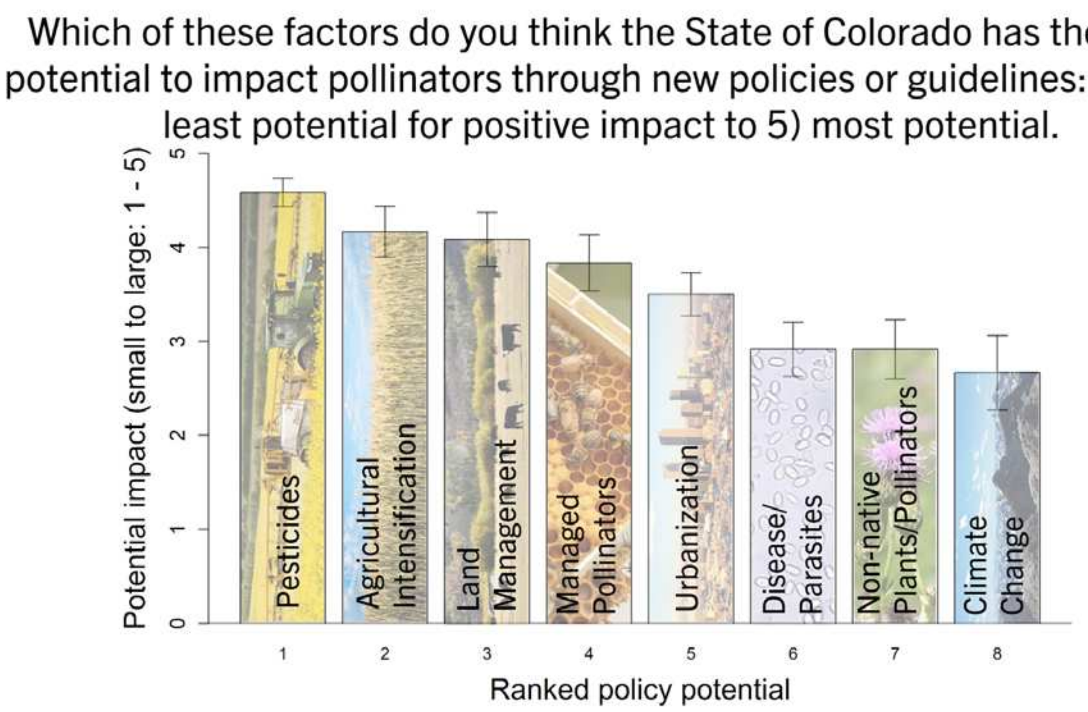
4.1. Priorities for Colorado Native Pollinator Health

Takeaways:

- Priority 1: Protect imperiled native pollinating insects.
- Priority 2: Protect, restore, and connect pollinator habitats.
- Priority 3: Mitigate environmental changes that negatively impact pollinators and their habitats.
- Priority 4: Reduce the risks from pesticides to pollinating insects.
- Priority 5: Monitor and support native and managed pollinator health.

Prioritizing needs in terms of changes in policy, management practices, and research is difficult, given the diversity of factors impacting native pollinating insects and the multitude of management recommendations that could help mitigate those impacts. However, the immediacy of declines in some groups, scope of impact of some factors, and availability of infrastructure or resources, can all be used to inform priorities and associated actions necessary to address pollinators in both the short- and long-term. To inform the development of these priorities, we surveyed 12 Colorado-based pollinator researchers to better understand what factors they believed our state agencies could impact the most through policy, and ranked the respective factors as mechanisms that drive pollinating insect communities (Figure 4.1). Overall, researchers identified pesticides as the biggest area where policy could have positive impacts on pollinators, followed by the drivers of habitat loss (agricultural intensification, land management, and urbanization), managed pollinators (such as honey bees), non-native species, and climate change. We use these rankings, in combination with feedback from state agencies, discussions with other stakeholders, and our synthesis of the science and management needs of pollinators in Colorado to prioritize areas for immediate action by the State. Below, we outline the five highest priorities for the State in addressing native

Figure 4.1. In a survey of pollinator researchers in Colorado, scientists consistently ranked pesticides as a policy area where the state has the most potential to positively impact pollinators through developing new policies or guidelines to help mitigate their negative effects.



pollinating insect health and discuss potential actions to address these priorities and better support native pollinators.

Priority 1: Protect Imperiled Native Pollinating Insects

Priority 1 is the highest priority for stemming pollinator decline: the protection of imperiled native pollinating insect species. The Uncompahgre fritillary (*Boloria improba acrocnema*), for example, is a federally endangered, endemic species found only in Colorado, and has one of the smallest ranges of any North American butterfly. The Pawnee montane skipper (*Hesperia leonardus montana*) is also a federally threatened, endemic species. Several other at-risk butterflies and bees are currently petitioned for listing with the United States Fish and Wildlife Service, and some of these native pollinating insects will likely be listed. **Listing under the federal Endangered Species Act is sometimes needed to stop imperiled species from sliding to extinction, but actions at the state level can help to ensure some of these species do not decline to the level of needing federal protection.** The Colorado State Wildlife Action Plan is an essential tool for the conservation of imperiled species, as it can generate federal funding for research, management, and recovery of species which can help keep species from being listed under the ESA. However, although Colorado Parks and Wildlife includes several pollinating insect species in the SWAP, the State lacks *specific language granting authority* over the management of insects or plants. This represents a major policy gap in the State's ability to manage at-risk pollinators and the plants that both support and depend on pollinating insects. Substantial gains in pollinator health and the conservation of imperiled species could be achieved by granting insect conservation authority to CPW or alternatively provide authority to the Colorado Department of Natural Resources which oversees CPW. These options would allow for the creation of policies or programs to protect imperiled pollinating insects.

Priority 2: Protect, Restore, and Connect Pollinator Habitats

Central to protecting imperiled species, and conserving pollinating insects in general, is to foster healthy habitats for their populations. **Priority 2** is to protect habitats important to imperiled species, and restore and connect habitats to support native pollinating insects, in general—and more broadly across the state. The practice of managing vertebrate species and their habitats is already well developed and the State regularly focuses on game, nongame, and at-risk species alike. Concepts such as protecting vulnerable habitats, restoring degraded habitats, and creating and managing habitat and habitat corridors are well developed for wildlife. **Extending these widely accepted concepts to insect and plant species would be particularly impactful in helping to protect and conserve ecosystems that depend on them.** Native pollinator health is intricately tied to plant health; the diversity of Colorado's native habitats, from its rangelands to alpine meadows, depend on sustaining the complex networks of plant–pollinator interactions. These networks support entire ecosystems, provide food for many of the most charismatic fauna of our state, and benefit humans indirectly through local wildflower tourism, bird and butterfly watching, and pollination of many crops. Providing authority to conserve insects and plants, and by extension the habitats they rely on, is a particularly efficient step to support native pollinator communities.

In addition to individual habitats, management actions and policy should consider how habitats and populations of plants and pollinators are connected across landscapes. Landscape configuration, i.e., the spatial distribution of different types of habitats, is extremely important to dispersal and foraging by pollinating insects, and is likely one of the most effective ways in which to foster restoration of insect communities in highly disturbed habitats. For example, while urban areas typically still offer small patches of habitats in yards and urban parks, corridors that connect those patches, including greenways, rights-of-way, and riparian areas, can provide crucial connectivity to link fragmented populations. By creating connections between habitats, land managers could promote native pollinating insects across scales, from local to landscape, and even across the state. Tracking or monitoring pollinators within those corridors could also allow researchers to better understand the role of habitat connectivity, heterogeneity (or variation), and the spatial distribution of resources in promoting native pollinator health across landscapes and administrative borders.

Priority 3: Mitigate Environmental Changes That Negatively Impact Pollinators & Their Habitats

In the long term, protecting imperiled pollinators and their habitats is only effective if combined with efforts to mitigate the negative factors driving their decline. Thus, **Priority 3** is to mitigate the human-caused environmental changes that negatively impact pollinators and their habitats. Human-caused environmental change is the primary driver of pollinator declines and encompasses a range of factors that change the amount and quality of pollinator habitat, as well as aspects of both the abiotic and biotic environments. We condensed the variety of potential drivers of environmental change to the three most significant: climate change, land-use change, and land management.

Climate change poses a unique challenge for future policy and management activities that address pollinating insects. **The negative impacts of climate change on native pollinating insects are some of the most well studied within the state, and the implications of those impacts for at-risk species such as high-elevation bumble bees and butterflies, are dire.** Continuing to create effective statewide policy and actions to reduce greenhouse gas emissions is therefore vital. **The state can address climate change by reducing greenhouse gas emissions and by capturing and storing carbon dioxide from the atmosphere through nature-based climate solutions.** Policies that could stem the drivers of climate change, such as reducing CO2 emissions, would represent hugely impactful changes to energy and climate policy. On the other hand, those policies are likely to have little short-term benefit for Colorado's pollinators. Focusing on nature-based solutions is one way to help limit carbon in the atmosphere, while simultaneously promoting pollinator diversity. Nature-based climate solutions have been shown to meaningfully contribute to climate mitigation. One study in the *Proceedings of the National Academy of Sciences* found nature-based climate solutions could contribute about 20% of the mitigation needed between now and 2050 to keep global warming below 2°C (3.6°F [Griscom et al. 2017]). Planting a diversity of trees, deep-rooted native grasses, forbs, and shrubs, and doing so even in urban and agricultural areas, can have a major positive impact. For instance, a recent study in California concluded that installing hedgerows on 50–80% of California's farmland would capture enough carbon to reach up to 12% of the state's greenhouse gas reduction goals (Chiartas et al. 2022). Importantly, these types of nature-based climate solutions provide resilience in these systems by buffering the impacts and providing an array of resources and refugia for pollinators during climate-driven extreme weather events, thus maintaining overall pollinator biodiversity.

There is also evidence that mitigating other drivers of pollinator decline that we can more easily control (e.g., pesticide use) can help species more effectively deal with the impact of climate change. Actions to address these other drivers will have more short-term benefits for species at-risk due to climate change, but should be accompanied by long-term plans and actions focused on the protection or restoration of imperiled habitats or ecosystems. Additionally, our pollinating insects can be a powerful tool to help drive action around climate policy. Bumble bees and butterflies, for instance, should be poster taxa for the impacts of climate change on biodiversity, with good evidence of recent declines driven by warming and drying climates across the western United States. Public interest in and concern for pollinators, especially if coordinated with statewide protection for the most imperiled species, could create positive feedback between management and conservation, fostering more resilient ecosystems able to cope with the worst effects of our changing climate.

Land-use change is the biggest driver of pollinator habitat loss; thus, policies that foster the protection, restoration, and creation of pollinator habitat within agricultural and urban landscapes would be particularly impactful. Although agricultural expansion has slowed as a result of our having already cultivated the majority of arable lands, urbanization is growing rapidly, and both represent threats to the conservation of pollinator habitats. Luckily, the factors that limit native pollinating insects in urban and agricultural habitats are similar, namely the availability of flowers, host plants, and nesting resources. Thus, policies or programs which focus on either creating habitats within those landscapes, or improving the value of existing landscaping for pollinators, could help mitigate the impacts of habitat loss. For instance, incentivizing the use of native plants in urban landscaping or cover cropping on farms, could help provide more floral resources for pollinating insects.

Some land management practices can negatively impact pollinators, while others can potentially either mitigate a related stressor or even foster more diverse pollinator communities. **Ultimately, the adoption of land management recommendations and policies to protect and promote native pollinating insects depends on engaging with practitioners, policymakers, and the public alike.** Colorado could be a leader in developing statewide policies addressing native pollinating insects by leveraging the pollinator research done within the state and utilizing policy examples from other states. Moreover, there are many municipalities and counties in Colorado, which have developed policies or guidelines that can be used to explore efficacy and scalability for application to agency- and state-level policy. Many municipalities will also look to this report, and to state agencies, for policy and management guidance. To best develop policy, interactions between different levels of government—in particular, collaboration on policy and recommendations on scalable issues—could be especially impactful.

Priority 4: Reduce the Risks from Pesticides to Pollinating Insects

The negative impacts of pesticides on pollinators are global in scale, but ultimately, are the result of local pesticide regulation and usage. Therefore, **Priority 4** is to promote policies and practices to reduce the risks that pesticides pose to native pollinating insects. There is broad scientific consensus that pesticides are related to declines in insects and that reducing pesticide exposure is likely an extremely important way to help conserve pollinating insects. Fundamentally, knowledge of how Colorado's at-risk pollinating insects are impacted by pesticides requires more information on what types of pesticides pollinators are exposed to across the state, and at what concentrations. Studies have shown that both native bees and managed honey bees in Colorado do have detectable amounts of an extensive suite of pesticides in their bodies and hives, and some in concentrations that have negative impacts on their health (see Section 2.3.7). However, the amount of information available on their exposure is from only a handful of locations, and mostly not within urban and agricultural areas, where environmental concentrations of pesticides are likely the highest. Policies to enable tracking pesticide exposure, would give managers a better understanding of the risk they pose, and how ultimately to mitigate those risks. Luckily, there are resources that state agencies could consider building upon. The Bee Informed Partnership for instance, has a honey bee health screening diagnostic test kit, which has an optional testing of the pesticide load of bee bread (food supplies in the nest) and wax. Encouraging beekeepers to contribute to data collection on pesticides through that program (whose data we summarize in section 2.3.7) would be a quick and efficient means of gaining a much broader understanding of where and when managed pollinators are exposed to pesticides across the state. While not necessarily directly correlated with wild pollinator pesticide exposure risk, as managed bees can be moved, fed, or otherwise managed to reduce their risk, honey bee health data would still be a powerful decision-making tool for state agencies. (Illustrating the importance of supporting and funding services like Bee Informed Partnership, as of the writing of this report, the partnership's future is unclear due to its reliance on external and inconsistent funding.)

Given that both managed and wild pollinators are being exposed to pesticides, ways to reduce that exposure are essential to mitigating the risks that pesticides pose. Some policies are already beginning to tackle this issue. For example, Senate Bill 23-266, passed and signed into law in 2023, required the Commissioner of Agriculture to designate neonicotinoid pesticides as "limited-use pesticides." This is one way to restrict their generalized usage as the "limited-use" designation will permit sales only by licensed dealers. In addition to restricting the usage of certain pesticides, there are myriad ways that land managers can reduce the risk of pesticides to pollinators, such as changing the timing of application, reducing usage, or adopting integrated pest management to explore alternative or integrative approaches to help mitigate pesticide risk (see Sections 3.2.5 and 3.2.6). Encouraging state agencies to adopt reduction- and mitigation-practice recommendations would be particularly impactful.

Pesticides are no doubt a highly controversial topic, given our reliance on them in many agricultural and horticultural systems; however, if pollinating insect conservation is a primary goal, consideration of their impacts and ways to mitigate them is crucial to protecting pollinators. **Ultimately, success in reducing pesticide exposure to pollinating insects requires investing in outreach and engagement to agricultural and urban sectors about the impacts of pesticides on pollinators and how individuals can help mitigate them.** Thus, supporting existing programs (like CSU Extension) or creating new programs or resources to help connect people with the expertise necessary to transition to alternative pest control strategies, would be effective ways to have a more informed and engaged public.

Priority 5: Monitor & Support Native & Managed Pollinator Health

A growing body of evidence suggests that managed pollinators, particularly honey bees, can have negative impacts on native pollinator health. However, pitting beekeepers and native pollinator conservationists against each other is likely counter-productive to both. Thus, **Priority 5** is to support both managed and native pollinators in the state. Honey bees can be an indicator of how pollinating insects in general are responding to human environmental change, as many mechanisms that drive native pollinator health (floral resources, pesticide exposure, and climate change) also impact honey bee health. However, monitoring health impacts on honey bees likely underestimate the true impacts on native pollinators, as honey bees are managed, often specifically to promote their health, while native pollinators are not. Still, given their dependence on shared resources (flowers), **managing habitats to benefit both honey bee and native pollinating insect health is an example of an area where cooperation between the state, beekeepers, municipalities, and the public could be extremely beneficial**. In general, beekeepers are very knowledgeable about resources within the environment and how they relate to honey bee productivity. Encouraging beekeepers to continue to engage with native pollinator conservation, and having open dialog between constituencies about how to mitigate negative impacts of honey bees on native pollinators is crucial to creating policies for sustainable honey bee management while simultaneously conserving native pollinators.

In general, **statewide policy around managed pollinators lags behind municipal policy, with some cities having already acknowledged a growing need to manage the impacts of the rapidly increasing interest in urban beekeeping**. Tools such as hive registration, licensing, and permitting can all help to limit indirectly the number of urban hives, while simultaneously promoting more informed urban beekeepers. Such local policies could also be an effective tool to help track data on the number of hives. Acquiring this information is the first step in better understanding honey bee impacts on native pollinators in cities across Colorado. Policies requiring education or training on the management and responsible husbandry of healthy honey bee hives for permittees could help mitigate the impacts of those hives even further. Municipal monitoring of native pollinators in conjunction with data collection on registered honey bee hives and health are really needed to best explore the impacts of honey bees, and also to develop the most informed recommendations on hive numbers, health, and management.

On the state level, the Colorado Department of Agriculture historically registered commercial beehives and required inspections for honey bee health. However, those programs were phased out and have created a gap in resources available for beekeepers and tools with which to track the health of managed hives. Creating **new statewide policy around honey bees, as well as new funding mechanisms for statewide training and monitoring, could be extremely impactful** in helping develop best management practices around honey bees, in addition to potential co-management recommendations for both managed and native pollinators. These state efforts could include programs to track honey bee health and resources for beekeepers to help maintain healthy and sustainable apiaries. The programs should also address the placement and potential impacts of honey bee hives, especially on State lands and in regards to the other management and conservation goals of state agencies, as honey bees do pose risks to native pollinating insects. Ultimately, having healthy and sustainable honey bee populations are of interest to both beekeepers and native bee conservationists.

4.2. Actions to Address Native Pollinator Health Priorities

Takeaways:

- State agencies should create pollinator strategies and implementation plans that include how pollinator conservation can be integrated with the current work of the agency, and what activities the agency can take to help pollinators.
- Develop a statewide pollinator conservation strategy for rare and declining pollinators and a roadmap for conservation and recovery of these declining species.
- Pursue statutory authority for invertebrates, including pollinator insects, to be managed as wildlife.

- Work with universities, colleges, and community scientists on applied research to answer important management questions and fill gaps of knowledge for at-risk pollinators.

While this study presents a tremendous amount of information available on both the science and management of native pollinating insects, there are nonetheless gaps in our understanding of both. Thus, the state should follow a multi-pronged approach to pollinator conservation by 1) taking immediate action on current best practices and agency policy and program recommendations, as described in Section 3 of this report, and 2) investigating areas of impact that have not been fully studied and how management can best mitigate negative impacts.

The presentation of potential management and policy recommendations in this study represents a synthesis of recommendations which, collectively, scientists, the study collaborators, and state land managers agree could be impactful for pollinators. Implementation of these practices by the State would represent a significant step towards conserving pollinators and their habitat. As documented in this study, many state agencies have a role to play in pollinator conservation. **We recommend that each agency creates a pollinator strategy and implementation plan.** These plans can include how pollinator conservation can be integrated with the current work of the agency, what activities the agency can take to help pollinators, the resources needed to implement these activities (such as funding, staffing, and expertise), and how it can work with other state agencies, nonprofits, researchers, the extension service, and others to implement these activities. We realize that each agency has a specific mission, but we believe that pollinator conservation activities could be incorporated where they align with that mission.

Additionally, as we gather more information about at-risk pollinators and those of greatest conservation need, **CPW or DNR—or both—working with researchers, nonprofits, and others, should consider developing a pollinator conservation strategy for rare and declining pollinators**. This strategy could identify a list of priority imperiled bee and butterfly species that occur in Colorado, assess threats for each, identify priority areas for their conservation, and recommend habitat management and restoration actions on state lands to benefit these animals. While an initial focus on bees and butterflies is appropriate to keep the scope of this effort manageable, future efforts should broaden the scope to include other categories of pollinators and invertebrates. A statewide plan, coupled with providing authority to manage insects by DNR and/or CPW, would provide a roadmap for conservation and recovery of these declining species and would be a positive step that will both benefit Colorado's ecosystems and help halt or reverse declines of these species and keep them from being listed under the federal ESA.

The lack of clear statutory authority for DNR and CPW to manage invertebrates as wildlife, including pollinating insects, represents one of the biggest gaps in the state's ability to manage and conserve pollinators, but also highlights a tremendous opportunity for the state to take an actionable approach to promote pollinator health. DNR and CPW fulfill a vital role for the conservation of Colorado's wildlife. Conservation programs and actions by these agencies are crucial for the recovery of vulnerable wildlife populations, ideally implementing effective conservation that prevents the need to list species under the ESA. Additionally, federal funding for research and conservation is often directed to species that are listed as Species of Greatest Conservation Need (SGCN) in the Colorado SWAP. Neither DNR nor CPW currently has management authority over bees, butterflies, and other pollinators, because these animals are not defined as "wildlife." The State should consider defining all invertebrates as wildlife under state code, which would allow DNR and CPW to effectively conserve imperiled pollinators. Providing similar authority to DNR and/or CPW for managing plants would also aid in the conservation of pollinator habitats. In states that have granted authority to their wildlife agencies, such as Washington, California, and Idaho, conservation actions follow. Examples include statewide strategies to protect imperiled bumble bees or other insect-related conservation projects for bees and butterflies. Granting specific authority could provide additional tools, access to external funding, and mechanisms for these agencies to better protect pollinating insects, and most importantly, at-risk species and their habitats.

Achieving many of the recommendations identified in this study will require policy support and guidance that simultaneously promotes research on the mechanisms of pollinator response to environmental change, while integrating science into the practical application of management and conservation principles. **This could be achieved through new collaborations between scientists and land managers to codesign studies to better inform science and management by using hypothesis-driven research to assess management outcomes.** These studies would be especially valuable if they incorporate multiple measures of impact and success, including any ecosystem-wide impacts or potential co-benefits of management activities. Also key to the success of such a framework would be developing ways to disseminate scientific findings and revised recommendations to communities and constituencies of interest. The latter is especially important in order to foster the adoption of best management practices. Integrating pollinating insects into the main sections of the upcoming revision of the SWAP, for example, could be an opportunity to emphasize the importance of and need for further research, collaborations, and conservation actions for imperiled pollinators. The SWAP is also tied to potential funding opportunities that could be beneficial for improving our knowledge gaps, as well as the conservation of pollinators in Colorado.

As new research is undertaken and management takes place, continued refinement of management recommendations and land management practices can improve conservation outcomes upon those best management practices. **The state should develop a framework for continued assessment of management activities that impact or benefit pollinators, and refinement of management practices based on**

Figure 4.2. Research and community science projects can gather data needed to track and guide the implementation of effective conservation measures for pollinators. The photos here show the steps in recording bumble bees for the Great Plains Bumble Bee Atlas. On the left is the netting (top) and capture (bottom) of a bumble bee. On the right is the identification and recording of observation data. The bumble bees are chilled with ice to make them lethagic and easy to handle. (Photos: Xerces Society / Katie Lamke.)

these assessments. A key to this refinement is the incorporation of management-oriented research into adaptive management strategies, wherein land managers should develop mechanisms to measure not only the narrow efficacy of, but also the nontarget impacts of, cost of, time commitment to, and feasibility of targeted conservation or management activities. This framework could allow practitioners to adapt broad management tools to fit the goals of individual programs or in different regions and habitats.

The investment by the State in this study provides foundational information for Colorado that can be used to begin establishing priorities and moving forward with actions to address those priorities. Coupling agency-specific pollinator strategies and implementation plans with a statewide strategy to conserve declining pollinators would be a powerful combination to address pollinator conservation in the state. Providing authority to DNR and/or CPW to manage insects fills a critical policy gap that is key to leveraging funding, resources, and agency ability to address pollinators and their habitats. Colorado's pollinator expertise, diverse pollinator community, and extensive protected and semi-natural lands mean these strategies could be especially impactful in aligning state resources and partner organizations to work collaboratively to conserve and enhance the health of our pollinators and their many important services.

4.3. Fostering Collaborative Conservation & Management

Takeaways:

- Build new collaborations with local and federal government partners, researchers, non-governmental organizations, and other community partners to maximize the development-speed and impacts of pollinator management and conservation.
- Cooperation across levels of government, collaborating with scientists, and engaging with a more diverse constituency, are all ways of accessing expertise in pollinators.
- Foster engagement by constituencies interested in or impacted by native pollinator conservation and management.
- Collaboration across state agencies and with other organizations could allow for large-scale efforts that promote pollinators across the landscape.

The State is not alone in its efforts to address pollinator health. **By building new collaborations with local and federal government partners, researchers, non-governmental organizations, and other community partners, the State can accelerate the development and impacts of pollinator management and conservation.** This would be extremely beneficial to the State, which could take advantage of the expertise, skills, and knowledge of collaborating groups, but would also enable those groups to expand their impacts by scaling up management and conservation practices to cover larger areas or more diverse communities. It could also benefit Colorado's economy, fostering new research, jobs, agricultural innovation, and even small businesses. In response to a staff survey from agencies that have a role in pollinator conservation, establishing pollinator habitat and research (71% of respondents) and study and research (48%) are the most common types of collaborations that occur. Education and outreach (29%) are the least common, indicating a potentially important area to develop collaborative opportunities around.

A significant area for collaboration is habitat creation and restoration, which requires the cultivation of native plants and the production of appropriate seed supplies by native plant nurseries. The increasing demand for native plants is still often unpredictable for nurseries, making many of them hesitant to dedicate resources toward scaling up production for fear of growing plants they cannot sell. Statewide policies and programs focused on restoration using native plants could therefore provide a stabilizing mechanism to help sustain nurseries that endeavor to grow native plants, and of particular value, spur conservation-motivated propagation of important pollinator plants. More stability in the market could also encourage new native plant growers to emerge. A successful example of this is how the Arizona Department of Transportation works with plant vendors 3–5 years in advance of a project and commits to using specific plant species. Over time, this has helped to stabilize the availability of plant materials, bring down costs, and increase capacity for plant providers. These efforts could also be done in collaboration with the Colorado State Forest Service Nursery, to create complimentary species lists for use in both the public and private sectors, effectively diversifying offerings of native trees and shrubs to different constituencies.

Expertise in native pollinating insects is an underlying requirement for the State to implement pollinator conservation. Acquiring such expertise could be done through creating devoted positions within state agencies to develop and implement pollinator strategies and programs, or in collaboration with institutions or organizations that already specialize in that expertise. Partner Biologists, for example, have been successful in fisheries and wildlife management, incorporating expertise from organizations such as Pheasants Forever, Ducks Unlimited, Bird Conservancy of the Rockies, and Trout Unlimited. These collaborative positions leverage the knowledge and expertise of those organizations to effectively engage vested communities and promote conservation practices. Similar positions could be created for pollinating insects, such as those that the Xerces Society and CSU Extension have with the USDA Natural Resources Conservation Service (NRCS). Additionally, the creation of collaborative positions within an agency or institution such as CDA, CDOT, or CSU Extension could help coordinate among programs of different agencies, provide technical guidance on pollinating insects, and assist with agency pollinator implementation plans, as described above. In reality, a combination of different strategies to incorporate expertise into statewide programs is likely a good approach to ensure the most impactful policy and practice around native pollinating insects.

Another key aspect to building collaborations is to foster engagement by constituencies interested in or impacted by native pollinator conservation and management. Diversifying stakeholder engagement should include outreach to private land managers, agricultural producers, ranchers, hunters and fishermen, outdoor enthusiasts, urban gardeners, conservationists, beekeepers, and indigenous tribes. All of these groups have a vested interest in pollinator health. Moreover, not only would they benefit from better pollinator conservation or management, they could also contribute to programs or efforts aimed at management or policy solutions. For example, consulting with indigenous nations, communities, and organizations offers an excellent opportunity to understand long-standing knowledge and expertise about the relationships and roles of pollinators and their habitats in Colorado. As another example, hunters and fishermen have long contributed data to inform CPW's management of game and fish, reporting not only harvested animals, but crucial biological data on age, sex, and disease within management units. The same approach could be used to incorporate constituent data into the monitoring of native pollinators. Other states such as Oregon, Washington, and Minnesota, for example, have implemented statewide monitoring efforts for native pollinators using some degree of participatory or community science, resulting in statewide distributional mapping of pollinators and even discovery of new populations of both non-native and endangered pollinator species (Satyshur et al. 2023). The Xerces Society is launching a Mountain States Bumble Bee Atlas in several states including Colorado in the spring of 2024, and there is an opportunity for state agencies to partner in this effort. Such efforts have and are likely to continue to have broad appeal to Coloradans interested in pollinator conservation. A highly collaborative approach to inventorying and

Figure 4.3. Engaging with expertise in pollinators can help train biologists and ecologists. Study coauthor Adrian Carper leads a pollinator course for the Boulder County Nature Association (top left), many of whom volunteer with open space agencies and are looking for training in how to sample native bees, such as this wool carder bee (*Anthidium* sp.; top right). Biologists from Boulder County Parks and Open Space invited Adrian Carper into the field for training in identifying nesting habitat for pollinators (bottom right), such as the western digger bee (*Anthophora occidentalis*; bottom left).

monitoring pollinators, including state agency involvement, could be an efficient route to improving our understanding of the distribution of pollinating insects and how they are impacted by human-caused environmental change.

The expertise in Colorado's research institutions likely represents one of the biggest opportunities for collaborative and impactful science on native pollinating insect management and research. Addressing the barriers to engaging scientists, especially those at academic research institutions, in studies relevant to pollinator management and policy, could help foster more applied (and impactful) research around how best to manage native pollinating insects and their habitats. In our survey of Colorado pollinator researchers, only 8% of researchers felt very knowledgeable about state policies, programs, or guidelines that addressed pollinators, with 58% feeling somewhat knowledgeable, and 33% not at all familiar with any policies or programs. Yet of those surveyed researchers, 92% thought that the lack of policy and management guidance and 83% thought the lack of technical training or knowledge were the biggest limitations to the state implementing native pollinating insect management practices. This disconnect between researchers with expertise and the land managers with the opportunity to implement policy on the ground, is a huge opportunity to bring together researchers and managers to study and inform management practices. Incentivizing researchers to engage is likely one route to foster those collaborations. Just half of those surveyed responded that they had worked with state agencies in some capacity, compared to 70% that worked with county and 80% with city governments. **However, 83% of researchers said that they would be willing to collaborate with state agencies on applied research**, with 17% responding that they might be willing to, and no respondents saying they would not. The biggest reasons for not conducting more applied research were a lack of available funding and prioritizing other research interests. Therefore, creating ways to support applied collaborative research, and to make applied research more broadly appealing, could foster more collaborative research and engagement.

Enhancing awareness and implementation of integrated pest management practices is another area that benefits from collaboration. This includes actions such as building on existing collaborations—and developing new ones—to increase understanding, awareness, and adoption of integrated pest management (IPM) and integrated vegetation management (IVM)—or evolve these into integrated pest and pollinator management (IPPM), an approach that incorporates actions that further support and protect pollinators while meeting pest management goals. These collaborations can also create opportunities to reach diverse habitats, including those in farms, rangelands, forests, roadsides, and municipal and residential lands. Creating and strengthening networks would benefit significantly from state-level collaboration and coordination with organizations like CSU Extension, researchers, and other stakeholders. Leveraging and expanding existing programs to support development of IPM and IPPM approaches in additional crop and non-agricultural systems could help to facilitate more careful pest prevention strategies and reduce the use of pesticides. Additional support for and prioritization of research and monitoring of pesticide contamination in the environment, wild bee responses to pesticides in field settings in Colorado, and the efficacy of different pesticide risk mitigation strategies could help inform these statewide efforts.

Creating new collaborative programs between state agencies could also have big impacts on both the research and application of management and conservation practices. This is especially true when different agencies could help mitigate the causes of pollinator decline. An example of the efficacy of agency collaborations is the partnership between DNR and CDOT to conserve Colorado's big game migration corridors, reducing wildlife collisions on roadways, and establishing wildlife crossings. Working together to study the situation, gather data, and develop solutions, this initiative is making roads safer for drivers and reducing risks and improving conditions for wildlife. Cross-department work between DNR and CDOT focusing on pollinator habitat linkages could achieve similar success for smaller wildlife. A second example of potential agency collaboration involves the State Land Board. The SLB manages over 2.8 million acres of mostly natural habitat, which is primarily leased for grazing, recreation, or energy production. The SLB has a mitigation bank program that currently is expanding to include voluntary biodiversity and carbon-sequestration projects. This program could also incorporate efforts to connect habitat restoration or conservation projects across SLB parcels and farms, specifically with the goal of supporting pollinators, helping to create more connected habitats and mitigating the impacts of habitat loss and fragmentation. Moreover, by including scientific research on effective strategies to mitigate the impacts of agriculture or grazing, agencies such as CDA, CPW, and SLB, collaborating together, could help further our understanding of how best to conserve pollinating insects in agricultural landscapes, while simultaneously improving best management guidelines for their respective agencies. The potential for large-scale implementation of such collaborative research projects would be very impactful, as landscape-scale studies of pollinator conservation practices are sorely needed.

Additionally, while expanding statewide habitat management to include plants and pollinators would represent a major improvement for conservation outcomes, it would still exclude a large amount of the biodiversity found in Colorado's ecosystems. For example, environmental changes that impact pollinating insects are also impacting the rest of Colorado's invertebrate species, which together represent a critical part of every ecosystem. **By further extending the concepts applied to habitat management to the management of entire ecosystems, policies could be designed to incorporate the multiple co-benefits of plant and pollinator management into the assessment of more meaningful management outcomes.** Although it is a lofty goal, moving beyond management focused on single species and into a more integrative, entire-ecosystem approach, one that incorporates science, socioeconomics, and ecosystem-scale measures of biodiversity and ecosystem services, would provide the most holistic assessment of both management and conservation practices.

4.4. Resources for Enacting These Recommendations

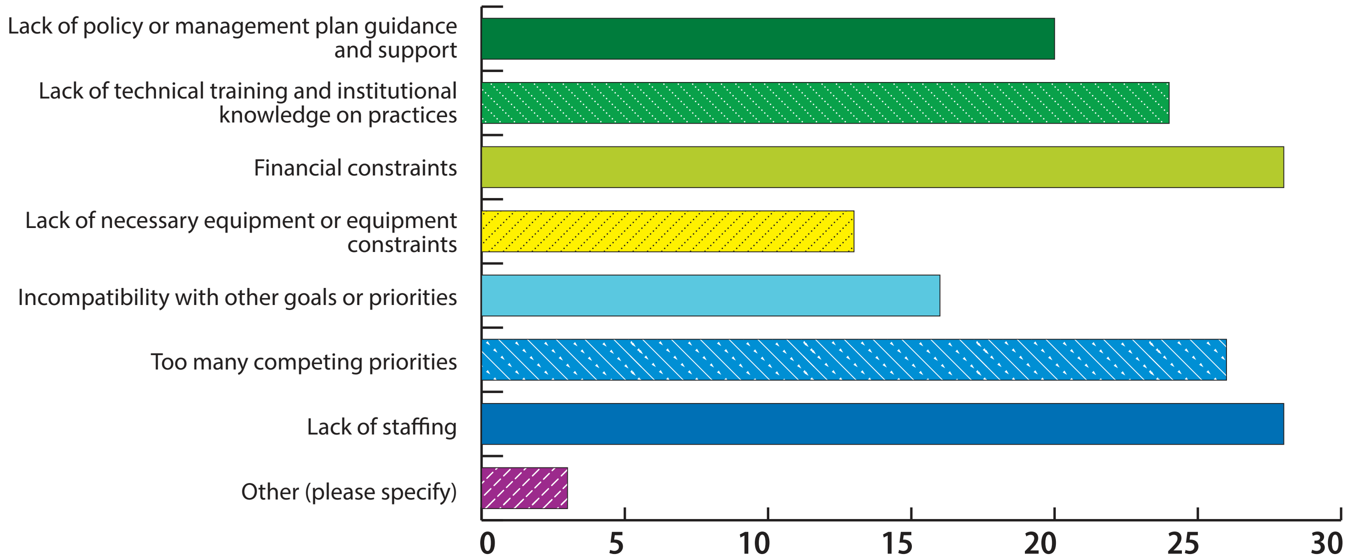
Takeaways:

- The State has many resources which could be used to further the conservation and management of native pollinating insects.
- Funding for programs, staff, training, and implementation are key to enacting policies and programs addressing native pollinating insects.
- Collaborators and cooperators can also contribute resources to help in research or the adoption of policies and recommendations focused on pollinator health.

In order to accomplish the recommendations provided in this study, the State will need to invest resources, time, and energy into policy, action, and infrastructure. Section 3.3 of this report discusses the range of policies and programs that state agencies already have in place that either directly or indirectly contribute to conserving pollinators and their habitats. These existing programs and policies are an important starting point for expanding and enhancing statewide efforts. Actions such as the designation of I-76 as a Pollinator Highway, with associated collaborative projects enhancing native plantings along this and other roadways, and the DNR Pollinator Conservation Policy Administrative Order DNR-108 supporting integrating pollinator-friendly provisions into relevant policies and management practices, are good examples of existing foundations that can be built upon.

While the development of new policy takes time and energy, infrastructure (whether physical or personnel) is needed to implement it. For example, if the DNR and/or CPW were given authority to work on insects, staff would be needed to implement recommendations for agencies within DNR and CPW that addressed pollinators. These staff would need expertise, or at least access to experts, who could translate the science and recommendations presented in this study to practitioners and land managers across the state. Providing additional training and education for those practitioners would also greatly improve the adoption and efficacy of any implemented management recommendations. A survey of state staff completed for the study included a question to identify the most important limitations to implementing pollinator-friendly management practices (Figure 4.4). Financial constraints, lack of staffing, competing priorities, and lack of technical training and knowledge were the most common limitations mentioned. Lack of policy or plan guidance, which this study helps to address, was also an important factor. Devoting resources to target

Figure 4.4: What do you see as potential limitations to implementing pollinator-friendly management practices on the land your agency manages or is responsible for?



these limitations will improve the ability of staff to implement the recommended conservation practices and programs.

While the recommendations described in this report may require new funding mechanisms, some could be achieved through collaboration, using resources already available to collaborating entities. CSU Extension is a prime example of an organization that is poised to collaborate and facilitate outreach and education on pollinator conservation across the state. CSU Extension serves all 64 counties of Colorado and has offices in 55 counties. CSU Extension faculty are embedded in their local communities and are driven to provide dynamic, science-based educational resources to the public on important and emerging community issues. **Field-based Extension faculty are the ideal conduits to bring pollinator education to the people of Colorado**, including ways to support native and managed pollinators, whether in their backyards or agricultural fields, or through engaging with policymakers and land managers. For the purposes of this study, Extension faculty were polled and asked whether they would increase their pollinator programming, if they were provided with necessary resources. Out of 52 respondents, 46 responded yes, with 5 responding that they are already doing a large amount of pollinator programming. When asked what resources are needed to incorporate more pollinator education into their overall programming, the top three answers were funding, training, and connections to experts. Finally, when asked what partners and agencies they either work with, or direct their clients to for pollinator education, responses included local municipalities, counties, local beekeeping clubs, USDA (NRCS and FSA), the Xerces Society, CPW, and other universities. Extension faculty are already collaborating with local and state agencies, and could leverage these relationships to bring in new pollinator programs.

Another resource for state agencies regarding the protection and conservation of native pollinating insects is the Colorado Natural Heritage Program. The CNHP is Colorado's comprehensive source of information on the status and distribution of Colorado's rare plants, animals, and natural plant communities. As Colorado's constituent member of the NatureServe Network, CNHP is now maintaining information on the location and status of rare pollinators to assess the status of pollinators on both global and statewide scales. Data compiled by CNHP are available to view and interact with through Colorado's Conservation Data Explorer

(CODEX; codex.cnhp.colostate.edu), an online repository and reporting tool of conservation data. CNHP currently tracks 164 insect species in Colorado (cnhp.colostate.edu/ourdata/trackinglist/). This represents just a small fraction of the State's pollinating insect diversity (see Section 2.2.2), covering only 6 out of more than 1,000 bee species, for example. However, the developed infrastructure CODEX provides could be improved through collaboration with pollinating insect experts. If insects were more comprehensively addressed in the SWAP as Species of Greatest Conservation Needs, collaboration between pollinator experts, state agencies, and CNHP could improve the data functionality of CODEX as a tool for CPW and other agencies that routinely use CODEX to inform conservation and management decisions. In addition, identifying Species of Greatest Information Need (SGIN) could help identify gaps in our distributional understanding of native pollinating insects in Colorado.

4.5. Conclusions

In summary, Colorado has an extremely diverse community of native pollinating insects. Although this community is relatively healthy in many parts of the state, these essential insects are nonetheless still at risk from the negative impacts of human-caused environmental change, and there is clear evidence that they may be declining in some areas. There also is growing evidence that management and conservation practices can help mitigate negative effects. Although a great deal of work has been done within Colorado—and in comparable regions in the western United States—more research, both fundamental and applied, will provide deeper knowledge to guide both management and conservation policy. **The legacy of human land use and management has had the most negative impacts on native pollinating insects. By implementing new conservation strategies, however, the State can help mitigate those impacts and foster more diverse and healthy pollinating insect communities.** Ultimately, in order to change how land is managed, and achieve the resulting benefits for our pollinators, a fundamental paradigm shift is needed in how land managers and the public think about pollinating insects. As foundational components of Colorado's ecosystems, the impacts of pollinating insect decline could be far-reaching and put much of the state's natural and agricultural resources at risk. As such, incorporating pollinators into management is vital to best manage our natural resources to be resilient and sustainable.

In the long term, measurements of the impacts of applied management practices on pollinating insects, and the ecosystems which depend on them, are needed to best inform adaptive management strategies. These management strategies would most effectively be developed in a collaborative framework, to take advantage of the expertise, resources, and communities invested in the health of the state's native pollinating insects. This paradigm shift also applies to how we design policy, to consider the incorporation of multiple measurements of impacts on both pollinators and people. By engaging with people across diverse constituencies, the State could help inform both agencies and the public about native pollinating insects, their roles in ecosystem and human health, conservation steps that everyone can take to help protect them, and ways in which everyone can effectively manage land with pollinators in mind. This would also enable the State to build more consensus about how best to create impactful policies and associated actions around pollinators and their conservation and management. Hopefully, this report will foster all of these activities and help Colorado ensure it has healthy native pollinating insect communities now and into the future.

Photo: Adrian Carper

Appendix I

Glossary of Terms

TERM	DEFINITIONS
abundance	The total number of individuals of a species or a group (such as all bees) found in an ecosystem or a site.
adaptive management	Using the results of new information gathered through a monitoring program to adjust management strategies and practices to help provide for the conservation of species and their habitats.
apiary	A place where honey bees are kept for commercial, hobby, or educational purposes; a collection of honey bee hives.
arid	Very dry, usually referring to a region that receives very little rain or other precipitation. Arid lands that receive less than 10 in./yr. of rain are referred to as deserts. In Colorado, arid lands are found west of the Rockies as well as in the San Luis Valley.
arthropods	A group of invertebrate animals, all of which have a hard exoskeleton (or outer structure) and jointed legs, that includes insects as well as crustaceans, spiders, and others.
biodiversity	The full array of living things considered at all levels, from genetic variants of a single species to arrays of species, genera, families, and higher taxonomic levels; includes natural communities and ecosystems.
brood	The young that hatch from a group of eggs laid at the same time by one mother.
Candidate Conservation Agreement	Formal, voluntary agreements between the US Fish and Wildlife Service and one or more parties, primarily federal agencies, created to address the conservation needs of one or more ***candidate species*** (see below) or species likely to become candidates in the near future; can be entered into with states, local governments, tribes, private property owners, and other entities.
Candidate Conservation Agreement with Assurances	Addresses species proposed for listing or candidates for listing on non-federal land; results in an enhancement-of-survival permit, which provides assurance to the applicant that if agreed-upon conservation actions for the covered species are implemented, the US Fish and Wildlife Service will not require additional conservation measures beyond those in the agreement should the species be listed. See also ***enhancement-of-survival permit***.
candidate species	A species that has been found warranted for listing as threatened or endangered under the US Endangered Species Act, but whose listing is precluded by higher priority species.

TERM	DEFINITIONS
canopy	The aboveground portion of a plant crop, formed by the collection of individual plant crowns; also refers to the upper layer or habitat zone formed by maturing tree crowns.
carbon sequestration	A natural or artificial process by which carbon dioxide is removed from the atmosphere, thereby stabilizing it in solid and dissolved forms to prevent it from causing warming of the atmosphere.
chrysalis	The pupal stage of butterflies, covered by a hard exoskeleton, inside of which they complete metamorphosis; typically found hanging from a surface.
climate change	Long-term shifts in temperatures and weather patterns, caused by human activities such as burning of fossil fuels and deforestation.
climate resiliency	The ability of species to adapt to and withstand changes in climate; biodiversity assists species in persisting over time as climate changes.
cocoon	The pupal stage of moths (and some other holometabolous insects) within which they complete metamorphosis; typically found hanging from a surface or buried underground or in leaf litter.
colony	Large community of individual bees living together as one social unit; typically includes workers, males, and a queen.
coloration	The colors, patterns, and general appearance used to identify species.
community	See *natural community*.
conifer	Woody plants that make cones, rather than flowers, in order to reproduce and are part of the Gymnosperm plant group. Most trees in Colorado are conifers, which include lodgepole pines, Colorado blue spruce, and Douglas-fir, among others
conservation	The use of habitat and other natural resources in ways such that they may remain viable for future generations. This includes permanent protection of such resources.
conservation action or measure	An action that, when implemented, would protect or restore and manage natural elements, including imperiled species and their habitats, natural communities, ecological processes, and wildlife corridors.
conservation easement	A voluntary legal agreement between a landowner and a land trust or government agency that permanently, or for a defined period of time, restricts uses of the land in order to protect its conservation values.
conservation status	The current status of the species as either listed in, a candidate for listing in, or petitioned for listing under the US *Endangered Species Act* or as imperiled without formal legal protection.
conservation strategy	Conservation actions or habitat enhancement actions that, if implemented, will sustain and restore species and their habitats, natural communities, biodiversity, habitat connectivity, ecosystem functions, water resources, and other natural resources.

TERM	DEFINITIONS
consultation	A process between the US Fish and Wildlife Service or National Marine Fisheries Service and a federal agency or applicant that: (1) determines whether a proposed federal action is likely to jeopardize the continued existence of listed species or destroy or adversely modify designated critical habitat; (2) begins with a federal agency's written request and submittal of a complete initiation package; and (3) concludes with the issuance of a biological opinion and incidental take (see *take*) statement by either of the two agencies.
corridor	Strips or patches of habitat that provide connections between larger patches of habitat.
creation (of natural community or species' habitat)	The creation of a specified resource condition where none existed before. See *establishment*.
crop pest	Includes seed eaters, herbivores, frugivores, and pathogens (e.g., insects, fungi, bacteria, and viruses) that can result in reduced agricultural productivity or total crop loss.
diapause	A physiological state of delay in development with reduced metabolic rate, in response to regular and recurring unfavorable environmental conditions; the time of the year and the stage of life when diapause occurs in insects vary among species.
disperse, dispersal	The movement of individuals from where they originate to other locations. In insects, the process of moving from the place their eggs were laid to another location or population where they will settle and reproduce; can occur in reaction to environmental conditions (weather and habitat quality) and social factors (variations in population density and sex ratio). *Migration* is a type of dispersal.
distribution	The spatial arrangement of individuals (usually of a given species) within their range. For example, while the whole state of Colorado may be within the range of a particular bee species, individuals of that species may be found at higher densities in certain counties or ecosystems (such as the Eastern Plains)
disturbance regime	The historic patterns (frequency and extent) of natural processes such as fire, insects, wind, and mass movement that affect the ecosystems and landscapes in a particular area.
diurnal	Active during the daytime.
diversity	See *biodiversity*.
dormant, dormancy	Having normal physical functions suspended or slowed down for a period of time.
ecoregion	As used in this document, ecoregion means a Section as defined by US Department of Agriculture. USDA describes four geographic levels of detail in a hierarchy of regional ecosystems: domains, divisions, provinces, and sections. Sections are subdivisions of provinces based on major terrain features, such as a desert, plateau, valley, mountain range, or a combination thereof.

TERM	DEFINITIONS
ecosystem	An interconnected system of living organisms that are found in an environment together, and the environment (the soil, water, and weather) that they interact with. For example, the alpine tundra is an ecosystem found above 11,000 ft. in Colorado's mountains, which includes all the plants, animals, and microbes that live in this cold environment with high winds and long, snow-covered winters. See *habitat*.
ecosystem function	The ecosystem processes involving interactions among physical, chemical, and biological components, such as dynamic river meander, floodplain dynamism, tidal flux, bank erosion, and other processes necessary to sustain the ecosystem and the species that depend on it.
ecosystem services	The beneficial outcomes to humans from ecosystem functions such as supplying of oxygen; sequestering of carbon; moderating effects of climate change; supporting the food chain; harvesting of animals or plants; providing clean water; recharging groundwater; abating storm, fire, and flood damage; pollinating and fertilizing for agriculture; and providing scenic views.
emergence	The appearance of organisms after a period of seasonal inactivity. Here, we refer specifically to when seedlings appear above the soil and when pollinators begin flying again after sheltering throughout the winter.
encroach, encroachment	The natural phenomenon characterized by the increase in density of certain types of plants, bushes, or shrubs at the expense of the herbaceous layer.
endangered species	A species that has become so rare it is in danger of becoming extinct throughout all or a significant portion of its range.
Endangered Species Act (ESA)	Federal law enacted in 1973 to prohibit the import, export, or taking of fish, wildlife, and plants listed as threatened or endangered species. The ESA also provides for adding species to and removing them from the list of threatened and endangered species and for preparing and implementing plans for their recovery; interagency cooperation to avoid take of listed species and for issuing permits for otherwise prohibited activities; cooperation with state governments, including authorization of financial assistance; and implements the provisions of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES).
endemic	A species, subspecies, or variety found only in a specified geographic region. For example, the Uncompahgre fritillary is an endemic butterfly found only in the northern San Juan and southern Sawatch mountains of Colorado. Due to their limited ranges, endemic species are generally considered to be at higher risk of extinction.
enhancement	A manipulation of an ecological resource or natural resource that improves a specific ecosystem function. An enhancement does not result in a gain in protected or conserved land, but it does result in an improvement in ecological or ecosystem function.
entomology	The scientific study of insects.
erosion (of soil)	The natural process of denudation of the upper layer of soil (topsoil) caused by water, ice, snow, air, plants, and animals; the process is accelerated by conversion of natural vegetation to cropland or pasture.

TERM	DEFINITIONS
establishment	The manipulation of the physical, chemical, or biological characteristics present on a site to develop an aquatic or terrestrial habitat resource for species. Establishment will result in a gain in resource area and/or function. See ***creation***.
extinction	The process of a species ceasing to exist, as no living individuals remain. Local extinction is when this process occurs within a limited area or location, but individuals still exist elsewhere in the world (see ***extirpation***).
extirpation	The situation in which a species or population no longer exists within a certain geographic area, while at least one other population of the species still persists in other areas; also known as local extinction (see ***extinction***).
fire regime	The pattern, frequency, and intensity of the wildfires that prevail in an area over long periods of time; an integral part of fire ecology and renewal for certain types of ecosystems.
fire return interval	The average period between fires, both natural and prescribed, under the historical fire regime.
flight period	The month or months of the year in which adult pollinators are observed in flight.
floral resources	Pollen and nectar, which are provided by flowers and which many adult pollinating insects use as food for themselves and/or their young.
food web	The overall food relationships (food chains) among organisms in a particular environment, detailing the interconnectivity in complex feeding relationships for that ecosystem. All the food chains in a single ecosystem represent the multiple possible paths that energy and nutrients may take as they move through the ecosystem.
forage	To search for food. Pollinators may forage for ***floral resources*** by flying to flowers during different seasons or different times of day.
forb	An herbaceous flowering plant other than a grass, sedge, or rush. These plants are generally the most important source of floral resources for pollinating insects and also host the developing larvae of some pollinators.
forewing	The anterior (front, closer to the head) wing of an insect, attached to the middle segment of the thorax.
fringe	A band of long, narrow scales along the outside edges of butterfly wings.
functional diversity	The variation in the roles that different organisms (usually species) play in an ecosystem. For pollinators, functional diversity can reflect differences in what plants they pollinate, how effectively they pollinate, and at what times of the year they visit plants.
generalist	Pollinators which can collect nectar or pollen from many species of plants across multiple plant families. Compare with ***specialist***.
guild	A group of organisms that use similar resources or share a trait, for example, bees that nest in the ground.
habitat	An ecological or environmental area that is, or may be, inhabited by a species of animal, plant, or other type of organism. Habitat is also the physical and biological environment that surrounds, influences, and is used by a species' population and is required to support its occupancy.

TERM	DEFINITIONS
habitat assessment	A process whereby habitat conditions are rated as optimal, suboptimal, marginal, or poor based upon descriptions and a rating scale.
habitat connectivity	The capacity of habitat to facilitate the movement of species and ecological functions. See also *landscape connectivity*.
habitat degradation	When habitat conditions decline due to invasive species, pollution, development, overutilization of natural resources, or other threats or stressors.
habitat enhancement	Actions that, when implemented, are intended to improve the quality of wildlife habitat or to address risks or stressors to wildlife. Habitat enhancement would have long-term durability, but would not involve acquiring land or permanently protecting habitat.
habitat fragmentation	When habitats are broken up into smaller patches, which may be too small to sustain populations of some species or species are unable to move between patches.
habitat loss	When habitat is eliminated or transformed into another type of land use.
habitat needs or requirements	In this publication, conditions that must be present in order for pollinator species to inhabit and thrive in their surroundings, including climate, vegetation, associated species, and natural processes.
habitat quality	The capacity of a habitat to support a species. The precise meaning of habitat quality varies by species and depends on the specific needs of a species in the context of a particular area. High-quality habitat for species may have only foraging and resting elements or it may include foraging, resting, and nesting elements. For other species, it may encompass all elements needed for the species to complete its life cycle. Low-quality habitat has only the minimal elements to support occurrence of the species. High-quality habitat tends to support larger numbers of species than low-quality habitat.
harm	As defined by the ESA, includes significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns, such as breeding, feeding, or sheltering.
herbaceous	Vascular plants with little or no persistent woody stems above ground; includes grasses and forbs.
herbicide	A substance that is toxic to plants, used to destroy unwanted vegetation.
heterogeneity	Variation in space or time. For example, a heterogeneous habitat for pollinators could have patches with bare ground and patches with dense plant growth, variation in what plants are growing and what time of year they flower, spots that are warmer or colder, and areas that are wetter or drier. A heterogeneous habitat can generally support a greater diversity of pollinators (and other organisms).
hindwing	The posterior (back) wing of an insect, attached to the last segment of the thorax.
holometabolous	Describing insects with four life stages: egg, larva, pupa, and imago (or adult).
host plant	Plants upon (or close to) which butterflies and moths lay their eggs, and upon which their caterpillars (larvae) will feed after hatching.
hymenopterist	A biologist who studies insects in the order Hymenoptera, which includes bees and wasps (important pollinators), as well as sawflies and ants.

TERM	DEFINITIONS
imperiled species	A species that is in decline and may be in danger of extinction. In this publication, this term identifies species that are not legally protected under the ESA.
infiltration (of water)	The movement of water into the ground from the surface.
instar	The stage of the insect between molts (the period when the insect sheds its exoskeleton).
introduced species	An organism not native to the place or area but accidentally or deliberately transported to the new location by human activity.
invasive non-native species	A non-native species that can spread into the ecosystems and displace native species, hybridize with native species, alter biological communities, and alter ecosystem processes and that has the potential to cause environmental or economic harm.
invertebrate	An animal without an internal skeleton
land conversion	The conversion of natural and agricultural land to other land uses through the process of development.
land cover type	The dominant feature of the land surface defined by vegetation, water, or human uses.
landscape connectivity	The extent to which the landscape facilitates or impedes movement among habitat patches. See also ***habitat connectivity***.
larva (plural larvae)	The active immature form of a holometabolous insect (which includes bees, wasps, butterflies, flies, and beetles) in the stage between egg and pupa. Larvae tend to look very different from adult animals and often have different habitat and food needs.
lepidopterist	A biologist that studies insects in the order Lepidoptera, which includes butterflies and moths (many of which are pollinators).
life cycle	The stages through which an organism passes during its life. For all insect pollinators, this includes four distinct life stages: egg, larva, pupa, and adult, which may occur in different habitats.
listed species	Species currently listed as threatened or endangered under the ESA; the species has been determined to be in danger of extinction in the near or foreseeable future by the US Fish and Wildlife Service.
managed bees	Bees that are bred and managed by people for commercial purposes. For example, honey bees kept for honey production or rental for commercial crop pollination. Managed bees often can harm wild pollinators through increased competition for nectar and pollen resources and spread of disease.
mesic	Containing a moderate or well-balanced supply of moisture
metamorphosis	A dramatic structural change in an animal between life stages. Complete metamorphosis involves four distinct life stages and is undergone by holometabolous insects.
microclimate	The atmospheric conditions of a very small or restricted area that differ from those in the surrounding areas.
migration	The movement of individuals among areas, generally directional and synchronized. See also ***dispersal***.

TERM	DEFINITIONS
mitigate, mitigation	To lessen the effects of an action, particularly adverse effects, on a species or habitat.
mitigation bank	A tool for replacing lost or degraded wetlands or other habitats and their functions as the result of development activities. Mitigation banks are sites where habitat is restored to meet statutory conservation requirements for habitat lost by an approved project. Common examples of mitigation banks are a site that is restored and/or managed as wetland or managed to provide habitat for listed species under the ESA.
mixed-conifer forest	A type of forest found in Colorado at altitudes between 7,500 and 10,000 ft., made up of a mixture of conifer species and quaking aspen. In contrast to the conifers, aspen produces flowers and loses its leaves in the fall.
monitoring	Data collected from repeated sampling to detect changes over time, such as in response to revegetation or maintenance practices.
monitoring protocols	The methodology used to collect data.
monoculture	The cultivation of a single crop in a given area.
National Environmental Policy Act (NEPA)	Federal legislation that promotes the enhancement of the environment by requiring federal agencies to assess the environmental effects of their proposed actions prior to making decisions and to incorporate environmental considerations in their planning and decision-making through a systematic interdisciplinary approach by preparing detailed statements assessing the environmental impact of major federal actions significantly affecting the environment.
native species	A species whose presence in a given region or ecosystem is the result of only natural evolution and distribution.
natural community	A group of organisms living together and linked together by their effects on one another and their responses to the environment they share. A general term often used synonymously with habitat or vegetation type.
natural resources	Biological and ecological resources including species and their habitats, including waters of the state, waters of the United States, wetlands, and natural communities.
NatureServe	A nonprofit organization comprising a network of conservation scientists that collects, aggregates, and standardizes data about the status and distribution of species and ecosystems of conservation concern in North America and assigns its own conservation rankings to such species.
nest	Places constructed and provisioned by bees and wasps in which their offspring develop; can be on the ground, in soil, underground, in tunnels, or in insulated cavities.
non-native species	Any species introduced after European contact and as a direct or indirect result of human activity to a new place or new habitat where it did not previously occur. See ***invasive non-native species***.
noxious plant	A plant that can directly or indirectly injure or cause damage to crops, livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment. The USDA Animal and Plant Health Inspection Service maintains a list of federally recognized noxious weeds, and each state also has its own list.

TERM	DEFINITIONS
objective, conservation objective	A concise, measurable statement of what is to be achieved and that supports a conservation goal. The objective should be based on the best available scientific information to conserve the species or other conservation elements for which the conservation goal and objective is developed.
overwinter	The process by which some organisms pass through or wait out the winter season, when conditions make normal activity or survival difficult or near impossible.
oviposit, oviposition	To lay an egg or eggs.
parasite	An organism that lives in or on a host, but does not kill the host.
parasitoid	An organism that lives on or inside a host and always kills the host.
pathogen	A bacterium, virus, or other microorganism that can cause disease.
perennial	Lasting or existing for a long time (in plants, more than 2 years); enduring or continually recurring.
pesticide	A substance used for destroying insects, plants, or other organisms.
petitioned species	A species for which a petition to list the species as threatened or endangered under the ESA has been submitted to the US Fish and Wildlife Service or National Marine Fisheries Service and is being evaluated
phenology	The timing of cyclic and seasonal natural phenomenon, such as when plants bloom and when insects emerge from pupal stages.
pollinator	An animal that helps carry pollen, either intentionally or accidentally, from the male part of the flower (stamen) to the female part of the same or another flower (stigma) to facilitate fertilization and production of fruit, seeds, and young plants. Most flowers are pollinated by insects and animals—such as bees, wasps, moths, butterflies, birds, flies, and small mammals, including bats. See also ***generalist*** and ***specialist***.
population	The number of individuals of a particular taxon inhabiting a defined geographic area. Populations cover larger geographic areas for pollinator species that can fly farther.
population decline	The reduction in abundance of individuals of a species, often as a result of human activity and climate change.
population growth rate	The speed at which the number of individuals in a population changes over time. Negative growth rates mean that the population is shrinking, positive means that it is growing.
pre-pupae	The stage just before the transformational stage for animals that undergo a dramatic transformation (metamorphosis) before becoming adults.
prescribed burning	The controlled application of fire by a team of fire experts under specified weather conditions to restore health to ecosystems that depend on fire.
programmatic	As opposed to a single defined project, indicating a suite of activities or a program encompassing multiple areas or projects.
proposed threatened	Any species the US Fish and Wildlife Service or National Marine Fisheries Service has determined is likely to become endangered within the foreseeable future throughout all or a significant portion of its range and proposed a draft rule to list as threatened

TERM	DEFINITIONS
pupa, pupate, pupation	In *holometabolous* insects, an insect in its immature form between larva and adult; usually inactive.
queen	In social insect species (e.g., honey bees and bumble bees), an adult female with fully developed reproductive organs who is usually the mother of all of the individuals in a particular *colony* and is responsible for laying the eggs. There is normally only one adult, mated queen in a hive or colony.
range	The area on a map within which individuals (usually of a given species) are found.
rangeland	Open country, usually grasslands, shrublands, woodlands, wetlands, or deserts, grazed by domestic livestock or wild animals.
reclamation	The act or process of recovering, or the state of being recovered. Many reclamation techniques can be used on the path to recovering or restoring pre-disturbance conditions.
recovery	The process by which the decline of an endangered or threatened species is halted or reversed or threats to its survival are neutralized, so that its long-term survival in nature can be ensured. Recovery entails actions to achieve the conservation and survival of a species, including actions to prevent any further decline of a population's viability and genetic integrity. Recovery also includes actions to restore or establish environmental conditions that enable a species to persist (i.e., the long-term occurrence of a species through the full range of environmental variation).
recovery area	On highways, the band of low-growing or routinely mowed vegetation directly adjacent to the pavement or shoulder of a road where vehicles that have left the roadway can recover; also known as the clear or safety zone. The recovery area is free of obstruction and the width is determined by the type of road and traffic volume, as well as the slope of the embankment.
refugia	Locations or areas providing a safe resting place for animals to hide from predators or shelter from habitat disturbance such as mowing or prescribed fire.
restore, restoration	In ecology and land management, actions taken to improve the health of an ecosystem that has been negatively impacted by human activities. Restoration efforts generally focus on removing or reducing human-influenced changes that are negatively impacting an ecosystem, as well as supporting or replacing species that have been lost or have declined.
revegetation	The process of replanting and rebuilding the soil of disturbed lands such as roadsides. This may be a natural process produced by plant colonization and succession, human-made rewilding projects, or accelerated processes designed to repair damage to a landscape due to construction or operational disturbance, wildfire, mining, flood, or other cause.
riparian	Relating to wetlands adjacent to rivers and streams.
roadside	Areas along the sides of roads and highways extending across both urban and rural landscapes; often the only natural vegetation that remains in highly altered landscapes. Roadsides can provide pollinators with a place to find food, reproduce, and take shelter or overwinter, and they can increase habitat connectivity.
roadside management or maintenance	The planning, design, construction, and maintenance of the non-paved highway right-of-way.

TERM	DEFINITIONS
semi-arid	Semi-dry, usually referring to a region that receives only a moderate amount of rain or other precipitation, but is wetter than arid lands. In Colorado, most of the state is semi-arid, which includes shrublands (often dominated by sagebrush) and pinyon–juniper woodlands found west of the Rockies and in the foothills of the Rockies, as well as the Eastern Plains.
senesce, senescence	To deteriorate with age because of the loss of a cell's power to divide and grow.
sensitive species	Any special-status species identified by a state or federal agency.
solitary	An animal that nests on its own. Solitary bees do not live in a communal nest or hive, with females building and provisioning nests on their own.
specialist	Pollinators which collect nectar or pollen from only one or a few species of plant. Compare with ***generalist***.
species	Aconcept used by biologists to categorize living things. Species are one of the narrowest categories, and a given species is generally distinguished as individuals that can reproduce with each other, though this definition is debated. Species are the level of biological organization that most people are familiar with and for which many common names are given. The painted lady (***Vanessa cardui***), for example, is a well-known butterfly species.
Species of Greatest Conservation Need	At-risk species identified in Colorado's SWAP that have the greatest need for conservation in the state.
Species of Special Concern	Species of Special Concern is an administrative designation and carries no formal legal status. The intent of designating SSCs is to: (1) focus attention on animals considered potentially at conservation risk by state, local, and federal governmental entities, regulators, land managers, planners, consulting biologists, and others; (2) stimulate research on poorly known species; and (3) achieve conservation and recovery of these animals before they meet criteria for listing as threatened or endangered.
State Wildlife Action Plan	A comprehensive plan for conserving fish and wildlife across the state.
status	See *conservation status*.
stewardship	Land planning and ecological resources management with the goal of protecting and enhancing ecosystems and biodiversity.
strategy	A plan of action or policy designed to achieve a major or overall aim.
succession	The process by which one habitat type is overtaken by another through changing dominance of pioneer species, altering the ecosystem dynamics. Early successional habitat contains vigorously growing grasses, forbs, shrubs, and trees that provide excellent food and cover for wildlife, but need disturbance to be maintained.
survey	Sampling conducted to determine the presence or absence of a particular species at a given site.
take	According to the ESA, any action to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." "Incidental take" is take of listed species that results from, but is not the purpose of, carrying out an otherwise lawful activity conducted by a federal agency or applicant.
thorax	The region of an insect body that follows the head and is before the abdomen; the thorax bears six legs and the insect's wings.

TERM	DEFINITIONS
threat	An anthropogenic (human-induced) or natural driver that could result in changing the ecological conditions of the species or its habitat in a negative way.
threatened	Plants and animals that are likely to become endangered within the foreseeable future throughout all or a significant portion of their ranges.
US Fish and Wildlife Service	The federal agency responsible for conserving, protecting, and enhancing fish, wildlife, and plants and their habitats, administers the ESA with the National Marine Fisheries Service.
univoltine	Having one generation per year.
vegetation management	The targeted control and elimination of unwanted vegetation and replacement with desirable vegetation.
ventral	Of, on, or relating to the underside of an animal or plant (abdominal).
woody plant	A plant, including trees and shrubs that produces hard stems that are made of wood. These plants provide important nesting resources for cavity-nesting pollinators and host the developing larvae of some many moths and butterflies. Some also provide floral resources (for example, willows are an important source of early season flowers in some parts of Colorado), though many do not.
worker	In social bees (e.g., bumble bees), non-reproducing females that collects food for other bees in the colony.
working land	Managed lands which are actively used for agricultural, ranching, forestry, or other productive purposes related to food and fiber production.

Acronyms and Abbreviations

TERM	DEFINITION
ALAN	Artificial Light at Night
AUMs	Animal Unit Months
BAMONA	Butterflies and Moths of North America
BMP	Best Management Practices
Btk	*Bacillus thuringiensis* var. *kurstaki*
CCA	Candidate Conservation Agreement
CDA	Colorado Department of Agriculture
CCAA	Candidate Conservation Agreement with Assurances
CDOT	Colorado Department of Transportation
CFLRP	Collaborative Forest Landscape Restoration Program
CNAP	Colorado Natural Areas Program
CNHP	Colorado Natural Heritage Program
CO_2	Carbon Dioxide
CPHE	Colorado Public Health and Epidemiology
CPN	Colorado Pollinator Network

TERM	DEFINITION
CPW	Colorado Parks and Wildlife
CRP	Conservation Reserve Program
CSP	Conservation Stewardship Program
CSU	Colorado State University
CU	University of Colorado
CUMNH	University of Colorado Museum of Natural History
CWHP	Colorado Wildlife Habitat Program
C4C	Corners for Conservation Program
DFPC	Division of Fire Prevention and Control
DOT	Department of Transportation
DNR	Department of Natural Resources
EA	Environmental Assessment
EIS	Environmental Impact Statement
EQIP	Environmental Quality Incentives Program
ESA	United States Endangered Species Act
FAQs	Frequently Asked Questions
FHWA	Federal Highway Administration
GSA	General Services Administration
IPM	Integrated Pest Management
IPPM	Integrated Pest and Pollinator Management
IRVM	Integrated Roadside Vegetation Management
IUCN	International Union for Conservation of Nature
IVM	Integrated Vegetation Management
MP_3	Colorado Managed Pollinator Protection Plan
NABA	North American Butterfly Association
NASS	National Agricultural Statistics Service
NEPA	National Environmental Policy Act
PPAN	People and Pollinators Action Network
ROW	Right-of-Way
RMBL	Rocky Mountain Biological Laboratory
SAP	Stewardship Action Plan
SCAN	Symbiota Collections of Arthropods Network
SFS	State Forest Service
SGCN	Species of Greatest Conservation Need
SLB	State Land Board
SSC	Species of Special Concern
STAR	Saving Tomorrow's Agricultural Resources

TERM	DEFINITION
STEM	Science, Technology, Engineering, and Mathematics
SWAP	State Wildlife Action Plan
USDA	United States Department of Agriculture
USGS	United States Geological Survey
USFWS	United States Fish and Wildlife Service

Appendix II

Potential Pollinator Partners & Collaborators

The following table lists organizations or programs that could provide partnership or collaborative opportunities and resources for state agencies and programs. This is not an exhaustive list and is only intended to illustrate some examples of potential partnership or collaboration opportunities. There are many other potential organizations, local government programs, and resources that also may be effective partners in pollinator conservation efforts.

CSU Extension

- **Description:** Offers educational resources to help people learn about pollinator conservation through volunteer programs and how to create and maintain pollinator habitat at residential and commercial scales..
- **Comments:** Provides pollinator outreach and education for everyone from youth to older adult learners

CSU Extension Native Bee Watch Program

- **Description:** A community science biodiversity monitoring project that began in 2016 at Colorado State University. The project is now a statewide program within Colorado State University Extension.
- **Comments:** Documents native bee diversity and abundance across Colorado, provides native bee training to community members, and promotes awareness about pollinator declines.

Colorado Natural Heritage Program

- **Description:** CNHP is Colorado's comprehensive source of information on the status and location of rare plants, animals and natural plant communities in the state. It maintains information on the location and status of rare pollinators and rare plants that depend on pollinators. CNHP is Colorado's constituent member of the NatureServe Network and uses a common methodology to assess the status of pollinators on both global and statewide scales.
- **Comments:** Data compiled by CNHP are available to view and interact with through Colorado's Conservation Data Explorer (CODEX), an online repository and reporting tool of conservation data (codex.cnhp.colostate.edu). Within CODEX, users can obtain conservation planning information on biological diversity, protected lands, and other natural resources. Data on Colorado's rare pollinators can be viewed alongside other biodiversity data for use in assessments and project planning.

People and Pollinators Action Network (PPAN)

- **Description:** Brings deep knowledge of and experience with pollinator protection, community development, environmental policy, sustainable agriculture, and habitat management. Staff and board members work closely to forge strategic wins for people, pollinators, and the state of Colorado

Butterfly Pavilion

- **Description:** The Butterfly Pavilion exists to foster an appreciation of invertebrates by educating the public about the need to protect and care for threatened habitats globally, while conducting research for solutions in invertebrate conservation.

Xerces Society for Invertebrate Conservation

- **Description:** The Xerces Society is an international nonprofit organization that protects the natural world through the conservation of invertebrates and their habitats. Xerces' interdisciplinary team offers unmatched expertise in finding solutions for conserving pollinators and other insects through habitat creation and restoration, pesticide risk reduction, and advocacy.

CU Museum of Natural History

- **Description:** The mission of the University of Colorado Museum of Natural History is to contribute to the knowledge of the natural world and human history through research, teaching, and public education. The museum houses the largest natural history collection in the Rocky Mountains. Currently, more than four million objects are categorized into five disciplines: Anthropology, Botany, Entomology, Paleontology, and Zoology. The collections include the world's oldest documented Navajo textile, the Aiken bird collection, and Colorado's largest collection of bees.

Denver Botanic Gardens

- **Description:** The Denver Botanic Gardens strives to entertain and delight while spreading the collective wisdom of the Gardens through outreach, collaboration and education. Their conservation programs play a major role in saving species and protecting natural habitats for future generations.

Colorado Commission of Indian Affairs

- **Description:** The Commission is committed to facilitating communication between the Southern Ute Indian Tribe, Ute Mountain Ute Tribe, the other 46 Historic Tribes of Colorado, American Indian/Alaska Native (AI/AN) organizations, state agencies, and affiliated groups.

American Indian Alaska Native Tourism Association

- **Description:** Founded in 1998, AIANTA was established by tribes for tribes to address inequities in the tourism system. Governed by an all-Native board of directors, AIANTA serves as a united voice for the $14 billion Native hospitality sector. AIANTA's priorities are:
    - » To provide technical assistance and training, research, and publications to american indian, alaska native, and native hawaiian communities engaged in tourism and hospitality;
    - » To facilitate conversations with the native communities, federal agencies, nonprofit associations, and elected officials on the economic and cultural importance of a healthy hospitality industry;
    - » To highlight the importance of visiting authentic native destinations, including cultural, heritage, historic, and artistic sites; and
    - » To generate awareness, interest, and demand for these destinations with domestic and international travelers, the travel trade, and the media

United Nations Educational, Scientific and Cultural Organization (UNESCO) Local and Indigenous Knowledge Systems (LINKS)

- **Description:** UNESCO's Local and Indigenous Knowledge Systems programme (LINKS) promotes local and indigenous knowledge and its inclusion in global climate science and policy processes. LINKS has been influential in ensuring that local and indigenous knowledge holders and their knowledge are included in contemporary science–policy–society fora on issues such as biodiversity assessment and management (CBD, IPBES), climate change assessment and adaptation (IPCC, UNFCCC), natural disaster preparedness (ISDR), and sustainable development (Rio+20, Future Earth). Working at local, national and global levels, LINKS strives to strengthen indigenous peoples and local communities, foster transdisciplinary engagements with scientists and policy-makers, and pilot novel methodologies to further understandings of climate-change impacts, adaptation, and mitigation.

Colorado Beekeepers Association

- **Description:** A unifying organization for affiliated regional and local beekeeping associations and clubs in Colorado.

Northern Colorado Beekeepers Association

- **Description:** The Northern Colorado Beekeepers Association (NCBA) is an organization of hobbyist and commercial beekeepers and is affiliated with the Colorado State Beekeepers Association. The NCBA mission is to encourage better beekeeping methods among members, encourage an interest in beekeeping among youth, and provide education to the general public about beekeeping and the contribution of honey bees to the welfare of the communities in Northern Colorado.
- **Comments:** List of Colorado beekeeping clubs and associations (nocobees.org/beekeeping-organizations/)

National Fish and Wildlife Foundation grant programs, Bee & Butterfly habitat fund programs

- **Description:** NFWF currently lists three grant programs that enhance pollinator habitat:
  - » Farmers for Soil Health
  - » Midwest Cover Crop Initiative
  - » Monarch Butterfly and Pollinators Conservation Fund

Bird Conservancy of the Rockies

- **Description:** Conservation of birds and their habitats through an integrated approach of science, education, and land stewardship.
- **Comments:** Conservation of rangeland and grasslands supports both birds and pollinators.

Pheasants Forever

- **Description:** Pheasants Forever's mission is to conserve pheasants, quail, and other wildlife through habitat improvements, public access, education, and conservation advocacy.

Audubon Rockies

- **Description:** Audubon Rockies is the regional office of the National Audubon Society that covers Colorado, Wyoming, and Utah. Using science, outreach, and policy, Audubon Rockies holistically address the core threats facing birds in the region.
- **Comments:** Promotes the Habitat Hero Program which promotes wildlife gardens for birds and pollinators

Denver Audubon

- **Description:** Inspiring actions that protect birds, other wildlife, and their habitats through education, conservation, and research.
- **Comments:** Denver Audubon is an independent chapter of the National Audubon Society.

Colorado Native Plant Society

- **Description:** A nonprofit organization dedicated to furthering the knowledge, appreciation, and conservation of native plants and habitats of Colorado through education, stewardship, and advocacy.

Colorado Association of Conservation Districts

- **Description:** CACD provides support to every county in Colorado through the 74 Conservation Districts that work with their local landowners and local communities.

Colorado Counties Inc.

- **Description:** CCI is a nonprofit, membership association whose purpose is to offer assistance to county commissioners, mayors, and council members and to encourage counties to work together on common issues.

Appendix III

Distributions of Colorado Bumble Bees

The heat maps below visually show the current geographic distribution and range of all 24 bumble bee (*Bombus*) species native to Colorado, in alphabetical order. The data came from the Global Biodiversity Information Facility (GBIF), the Xerces Society, and other unpublished sources. The data are concentrated in locations with institutions with bee researchers (e.g., universities, museums, RMBL). Further, there are locations with no or limited data including the four corners of Colorado, Southern and Southwestern regions along the Arkansas River, the Comanche and Cimarron National Grasslands, and the Eastern Plains of Colorado. Despite the data gaps, species with narrow distributions and with >1,200 observations in Colorado include *Bombus balteatus*, *B. mixtus*, *B. fervidus*, and *B. nevadensis*. The latter three have been designated as critical of becoming endangered by the World Wildlife Fund. Those with wide distributions and with <300 observations, included *B. californicus*, *B. fernaldae*, *B. frigidus*, and *B. suckleyi*. Most of the species are concentrated in the mountain regions or along the Western Slope, except for *B. pensylvanicus*, *B. fraternus*, and *B. variabilis*, which are found in the eastern part of the state. Based on the available data, other species of concern besides those with narrow distributions, include *B. auricomus*, *B. suckleyi*, and *B. variabilis*.

The maps were produced by MS graduate students Tandie Gautreau, Devin Arnold, Casey Caduff, and Antonio Luna-Galindo as part of their capstone project in the Department of Geography and Environmental Sciences at CU Denver. A kernel density estimation was employed to smooth the occurrence data and then the smoothed data were visualized based on the density or intensity of the data using color values (i.e., heat maps) using ArcGIS software (Greenens 2021; Gehlenborn et al. 2012). Future data collection for all pollinator species should be spatially distributed across Colorado, with a focus on locations where data are sparse. Further, existing data needs to be gathered and cleaned to assure that species of interest and questions can be quickly and accurately mapped. Distribution modeling could also be explored to predict where certain species should occur and then sampling efforts could be targeted in those locations.

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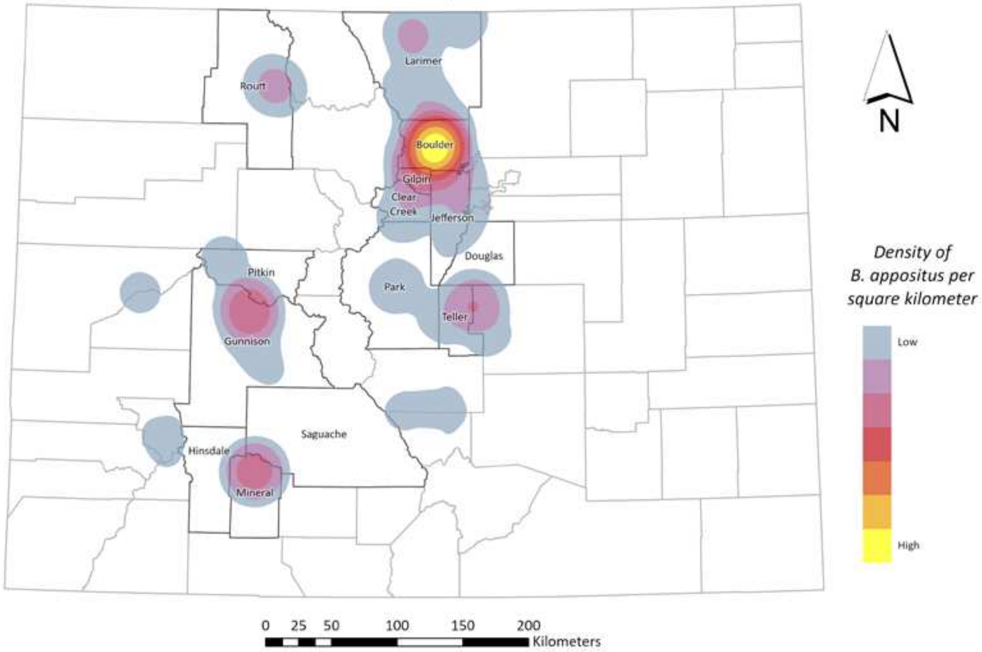
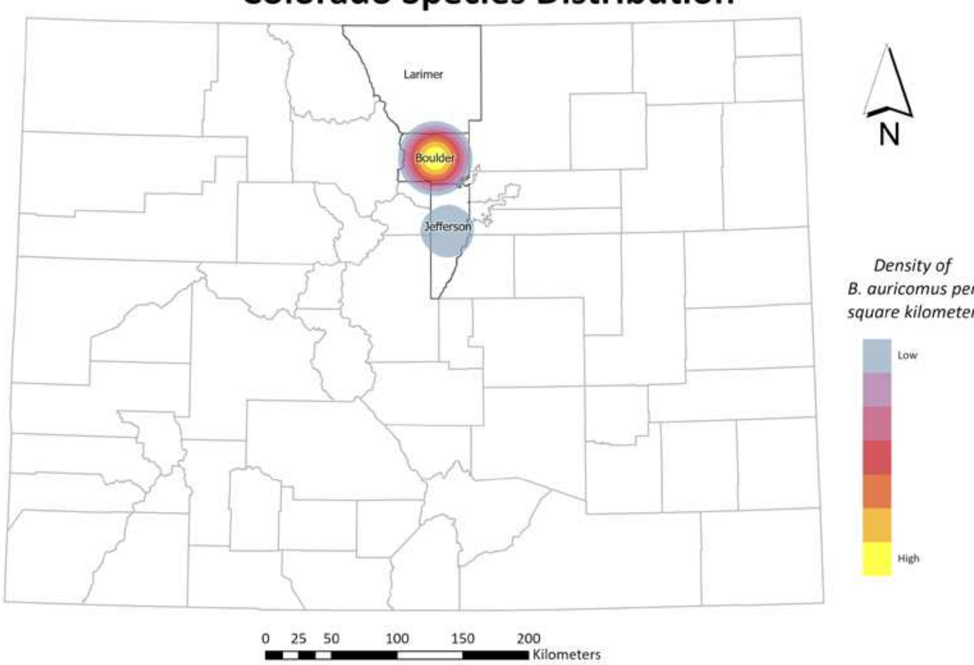
Geenens, G. (2021). Mellin–Meijer kernel density estimation on R." *Annals of the Institute of Statistical Mathematics*, vol. 73(5), 953-977. https://doi.org/10.1007/s10463-020-00772-1

Gehlenborg, N., and B. Wong. (2012). Heat maps. *Nature Methods*, vol. 3(9), 213-213. www.bcgsc.ca/downloads/cydney-test/refs/Gehlenborg_Wong_03.2012_NM.pdf

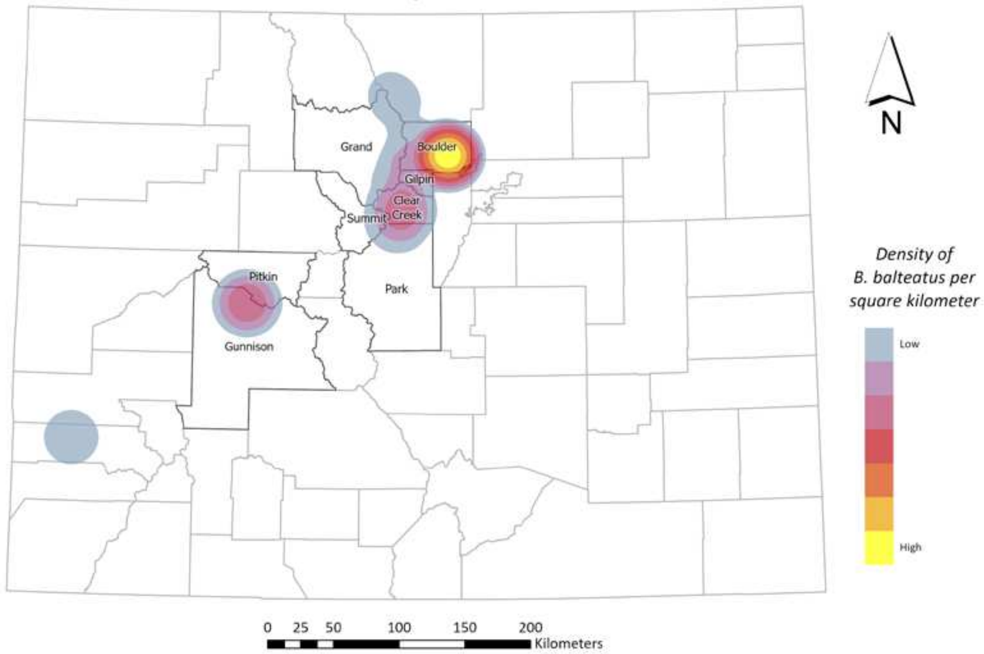
White-shouldered Bumble Bee (*Bombus appositus*) Colorado Species Distribution



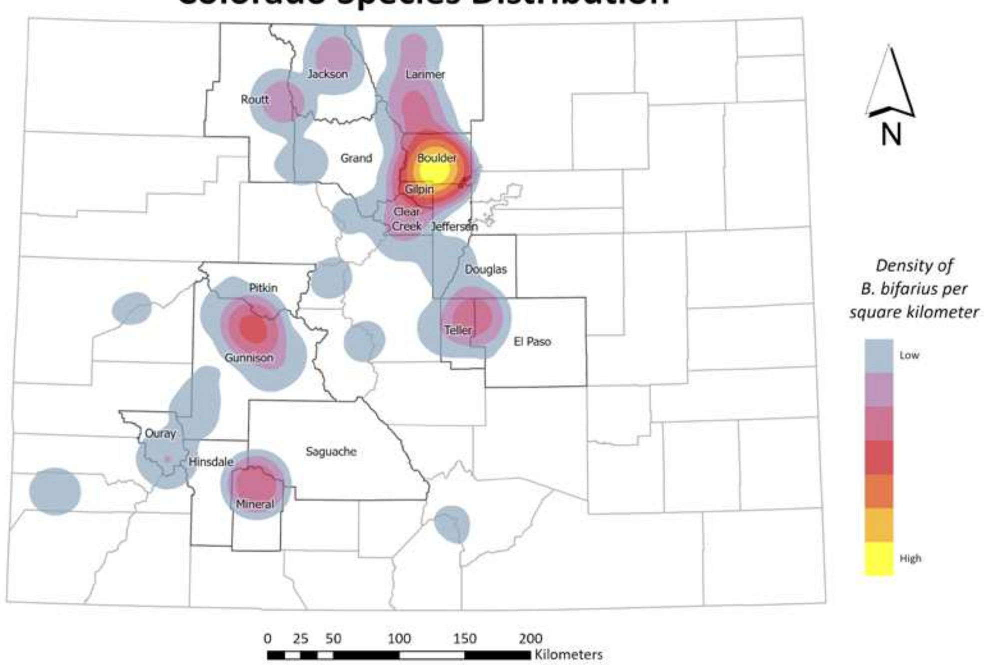
Black and Gold Bumble Bee (*Bombus auricomus*) Colorado Species Distribution



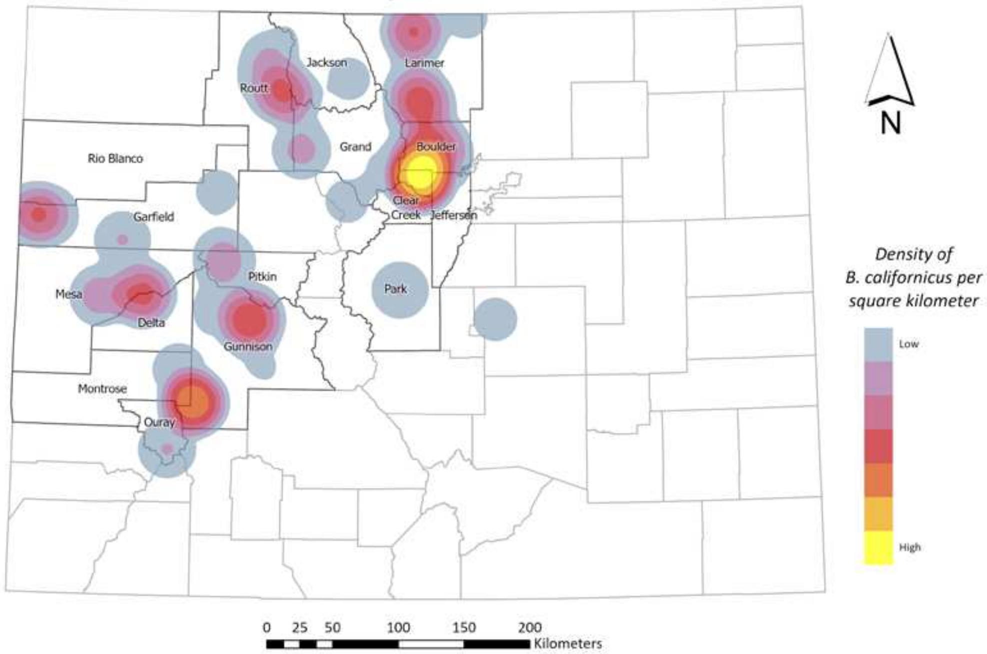
Golden-belted Bumble Bee (*Bombus balteatus*)
Colorado Species Distribution



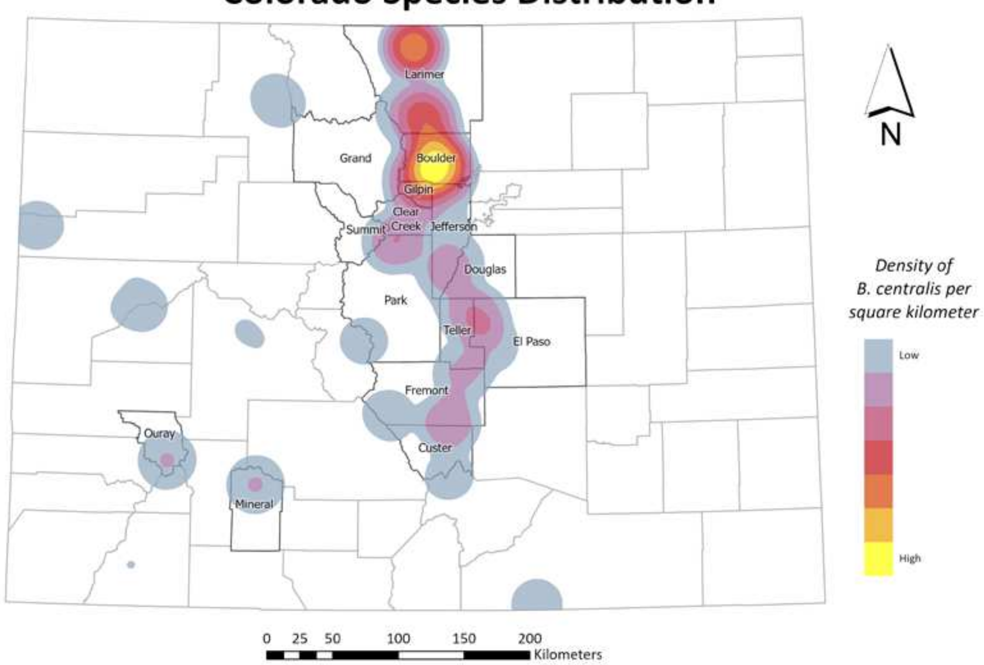
Two-form Bumble Bee (*Bombus bifarius*)
Colorado Species Distribution



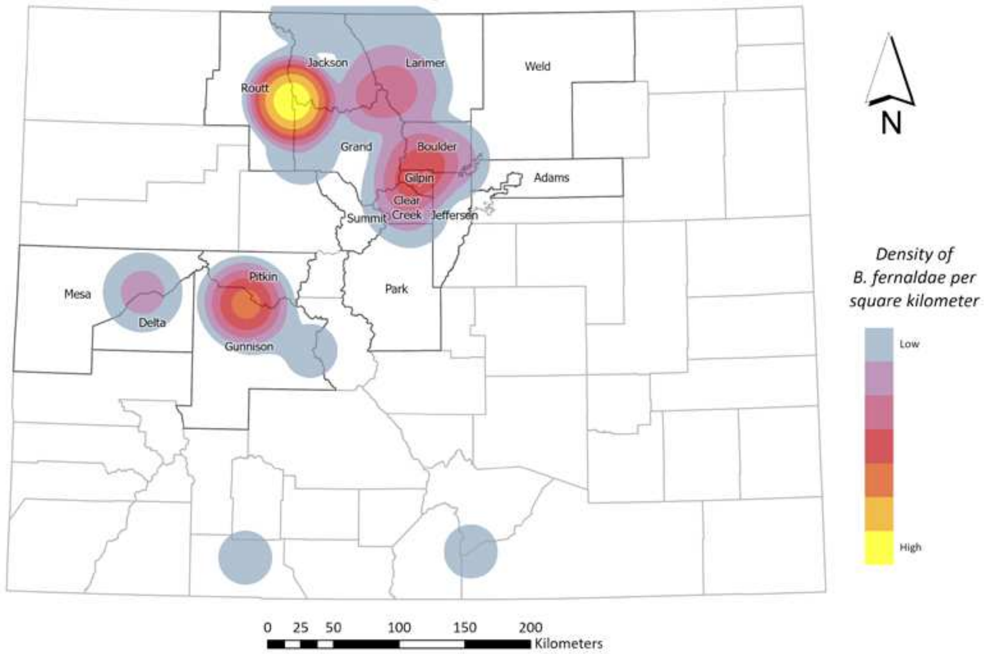
California Bumble Bee (*Bombus californicus*)
Colorado Species Distribution



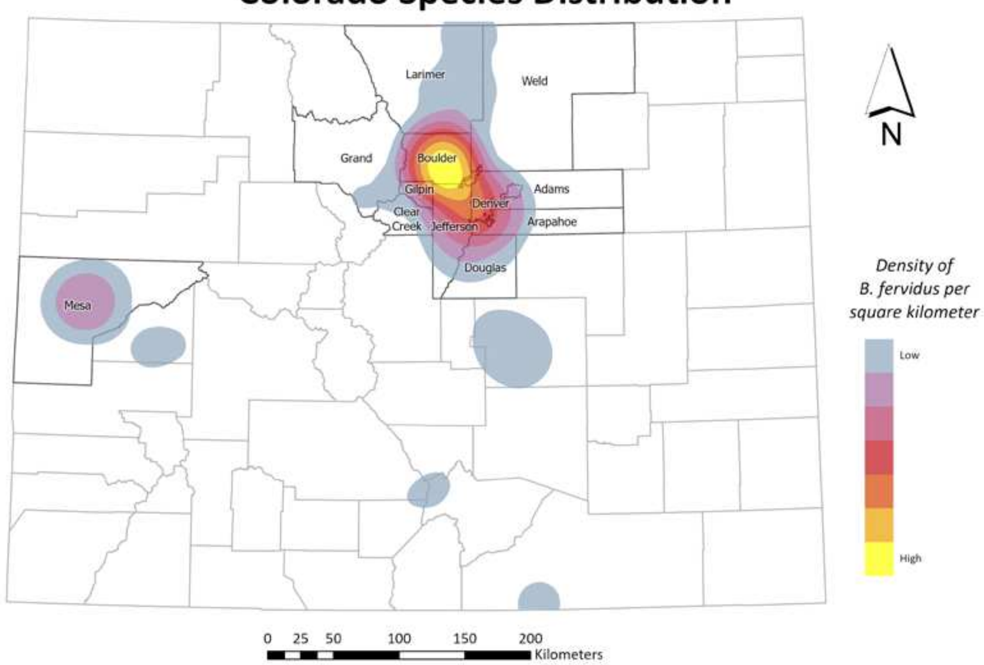
Central Bumble Bee (*Bombus centralis*)
Colorado Species Distribution



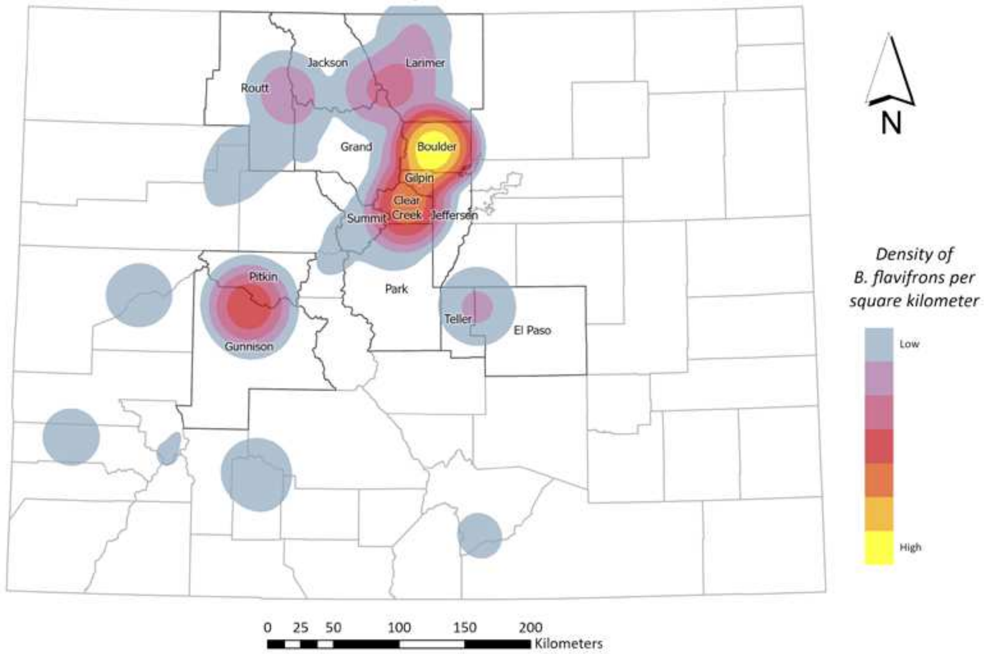
Fernald's Cuckoo Bumble Bee (*Bombus fernaldae*)
Colorado Species Distribution



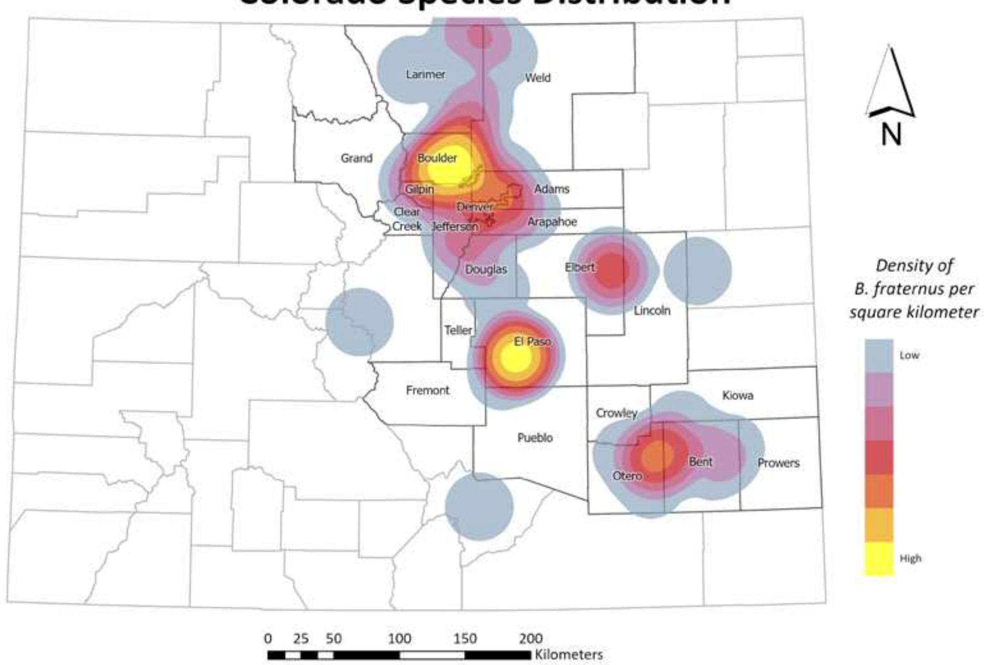
Golden Northern Bumble Bee (*Bombus fervidus*)
Colorado Species Distribution



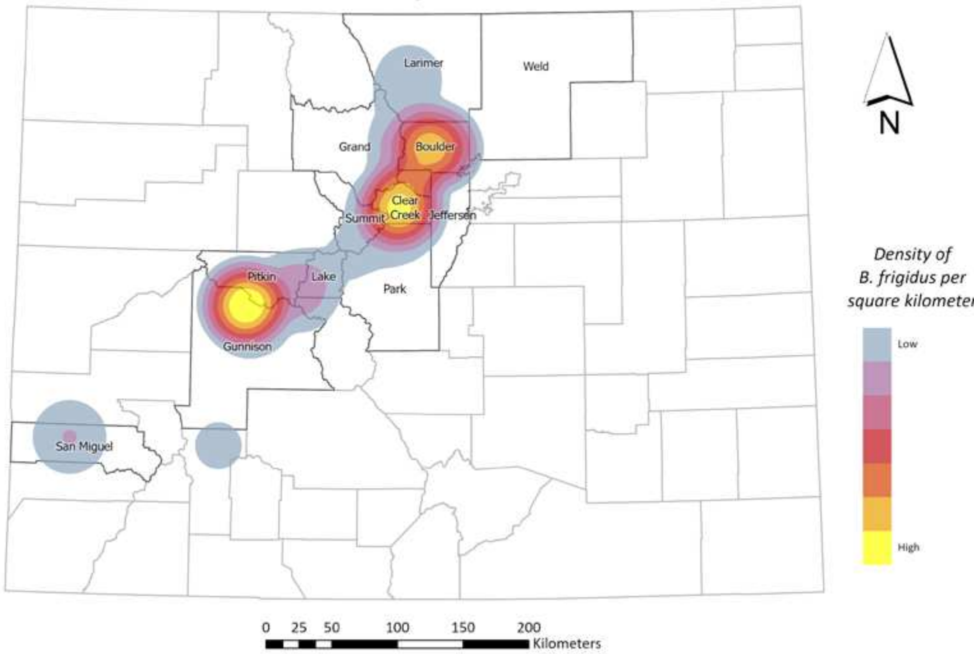
Yellow-fronted Bumble Bee (*Bombus flavifrons*) Colorado Species Distribution



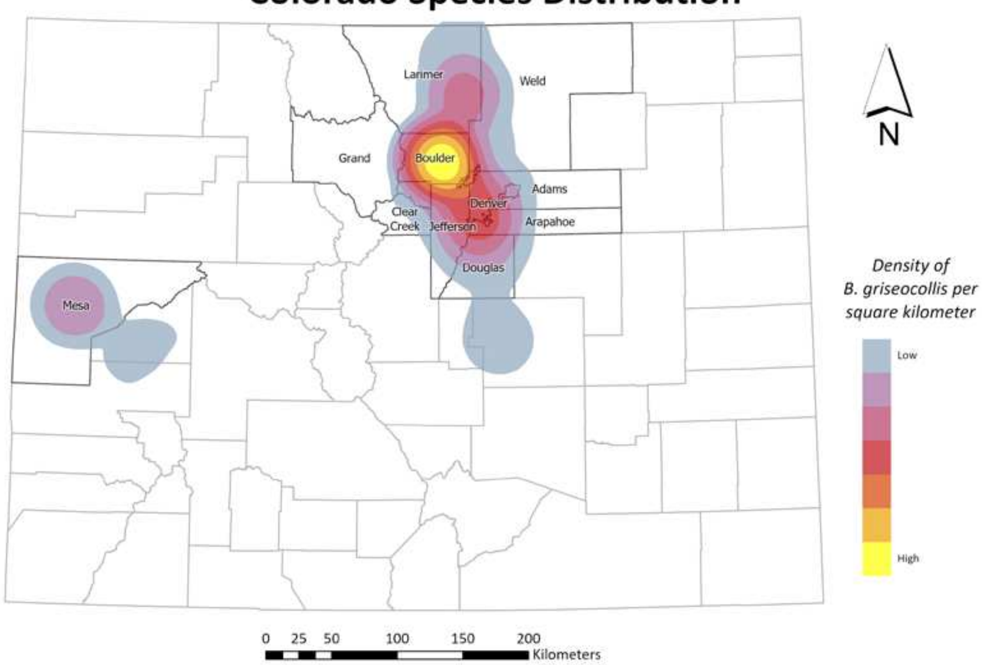
Southern Plains Bumble Bee (*Bombus fraternus*) Colorado Species Distribution



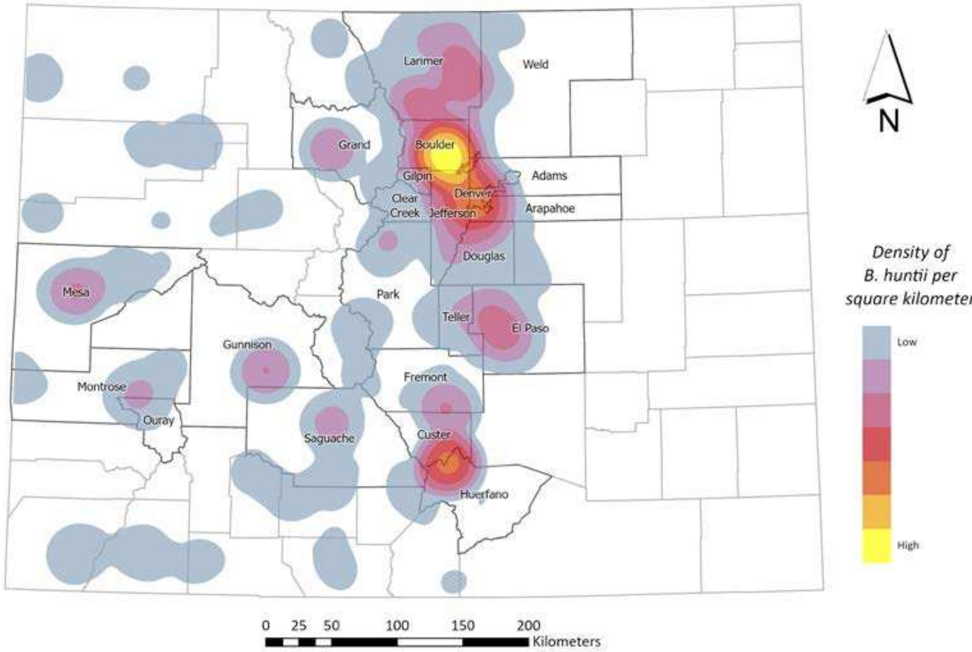
Frigid Bumble Bee (*Bombus frigidus)* Colorado Species Distribution



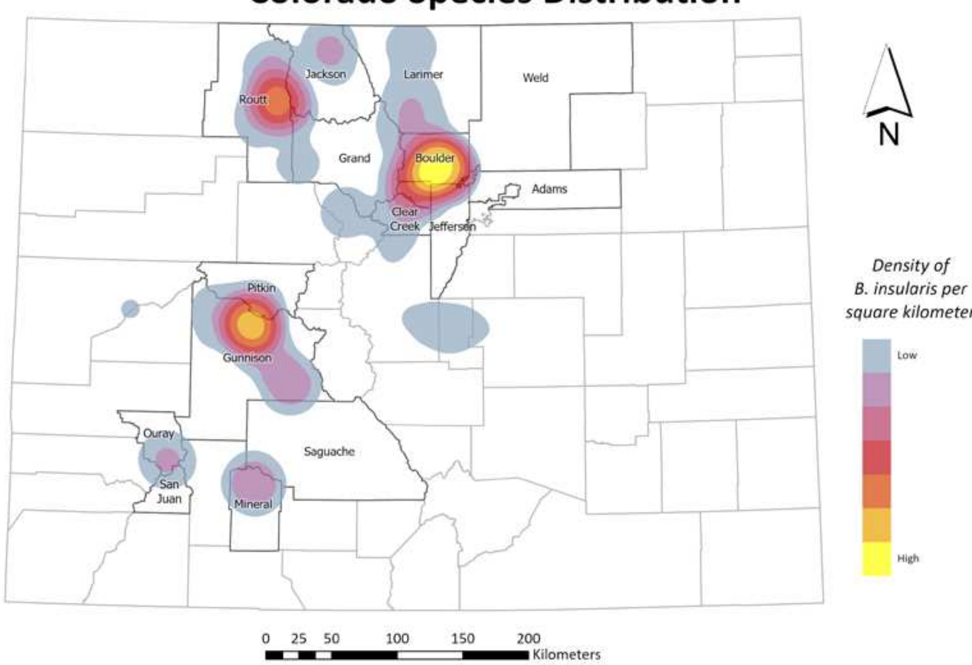
Brown-belted Bumble Bee (*Bombus griseocollis)* Colorado Species Distribution



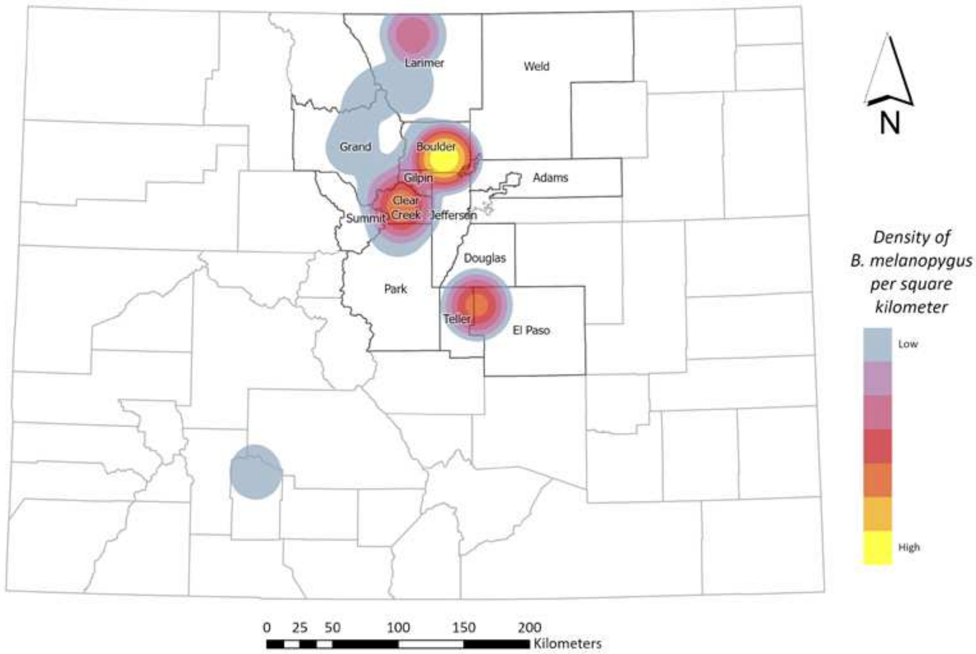
Hunt Bumble Bee (*Bombus huntii)*
Colorado Species Distribution



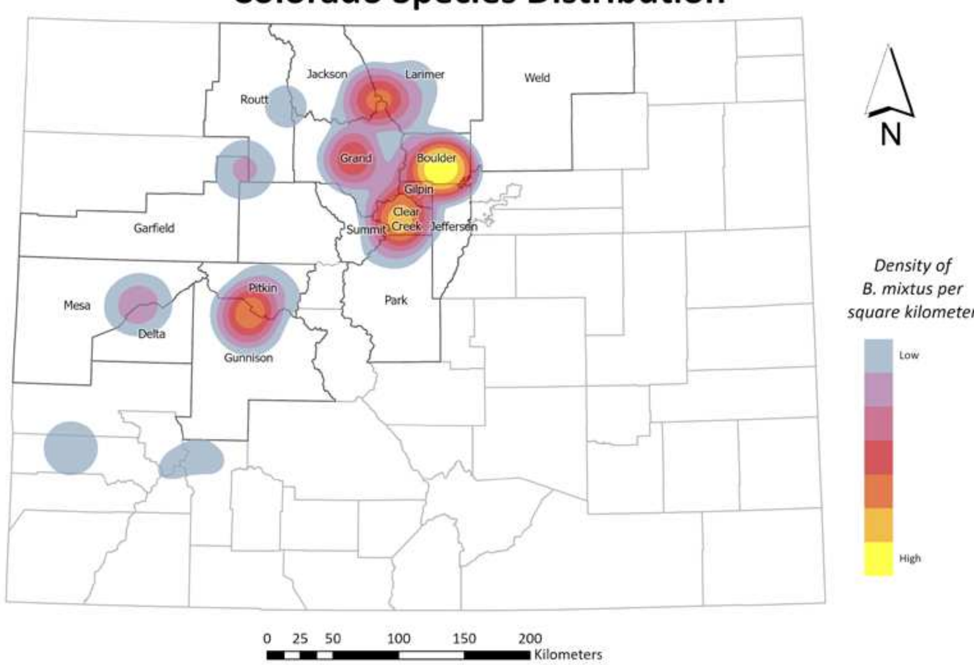
Indiscriminate Cuckoo Bumble Bee (*Bombus insularis)*
Colorado Species Distribution



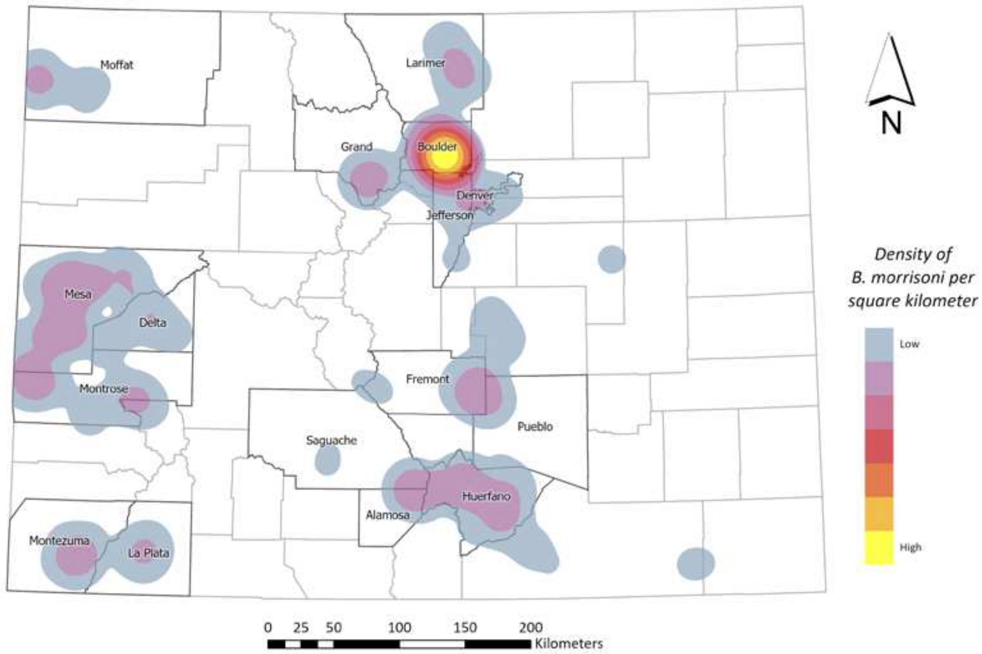
Black-tailed Bumble Bee (*Bombus melanopygus*) Colorado Species Distribution



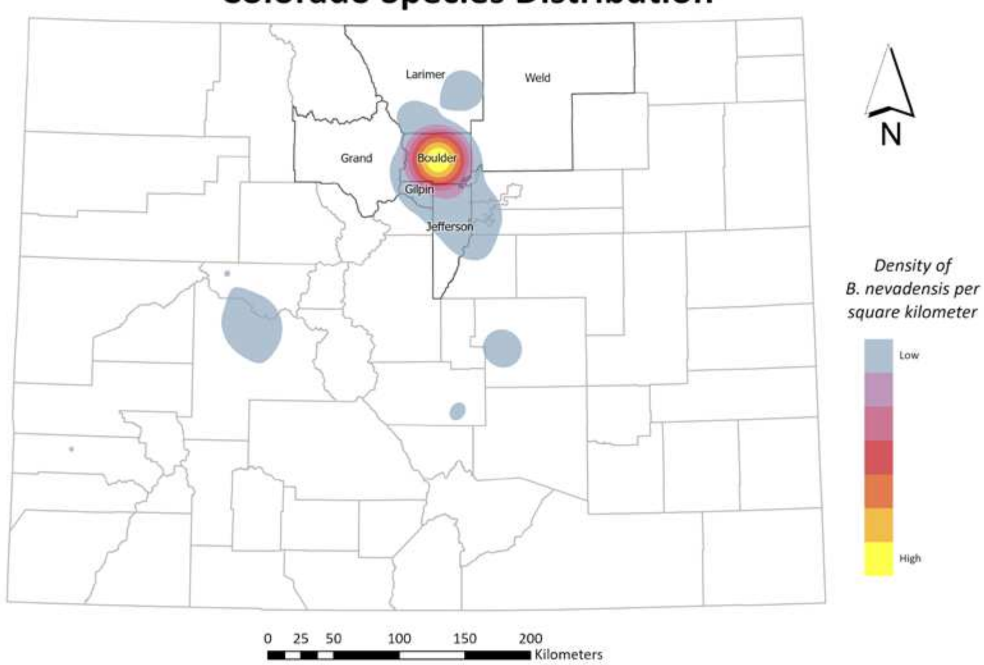
Fuzzy-horned Bumble Bee (*Bombus mixtus*) Colorado Species Distribution



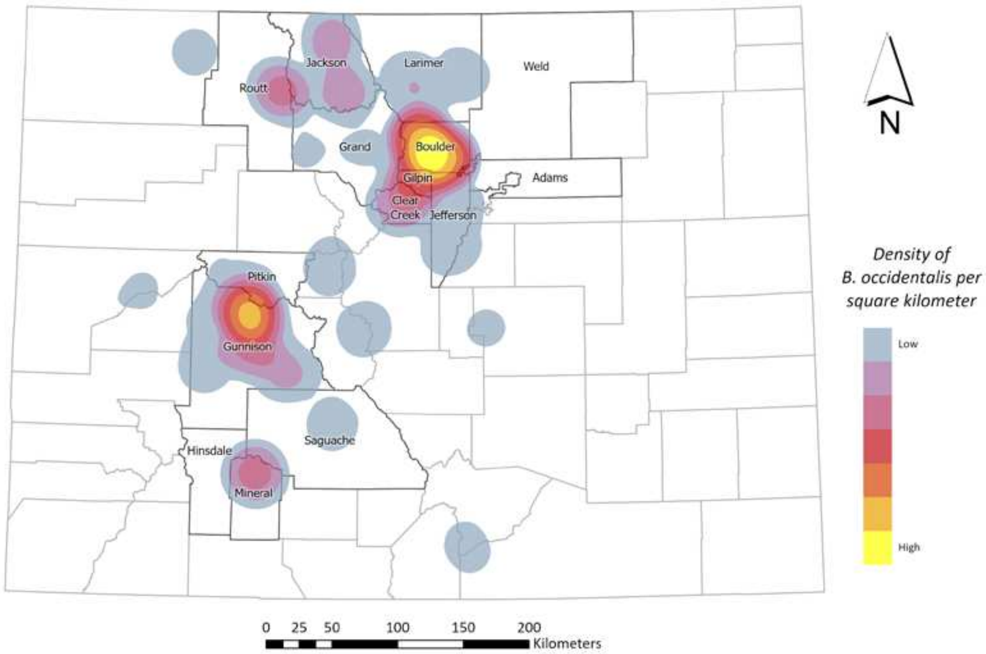
Morrison Bumble Bee (*Bombus morrisoni*)
Colorado Species Distribution



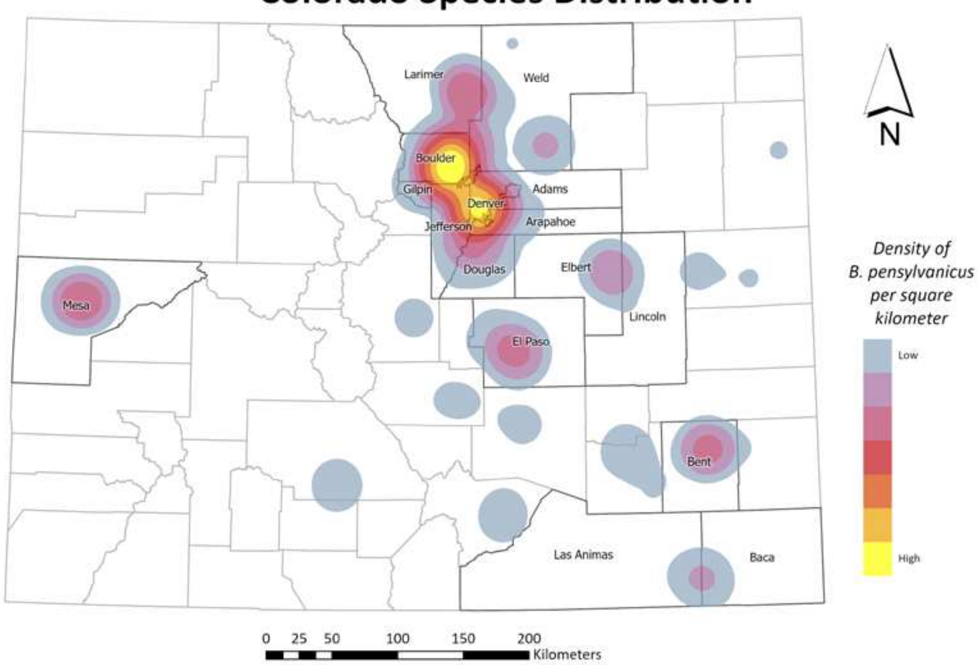
Nevada Bumble Bee (*Bombus nevadensis*)
Colorado Species Distribution



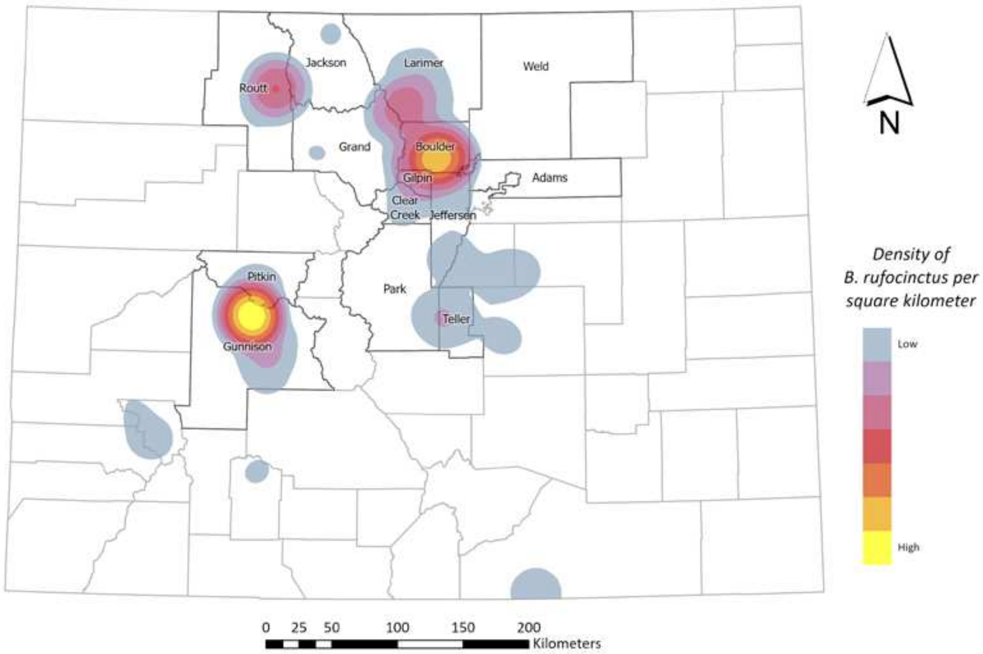
Western Bumble Bee (*Bombus occidentalis)*
Colorado Species Distribution



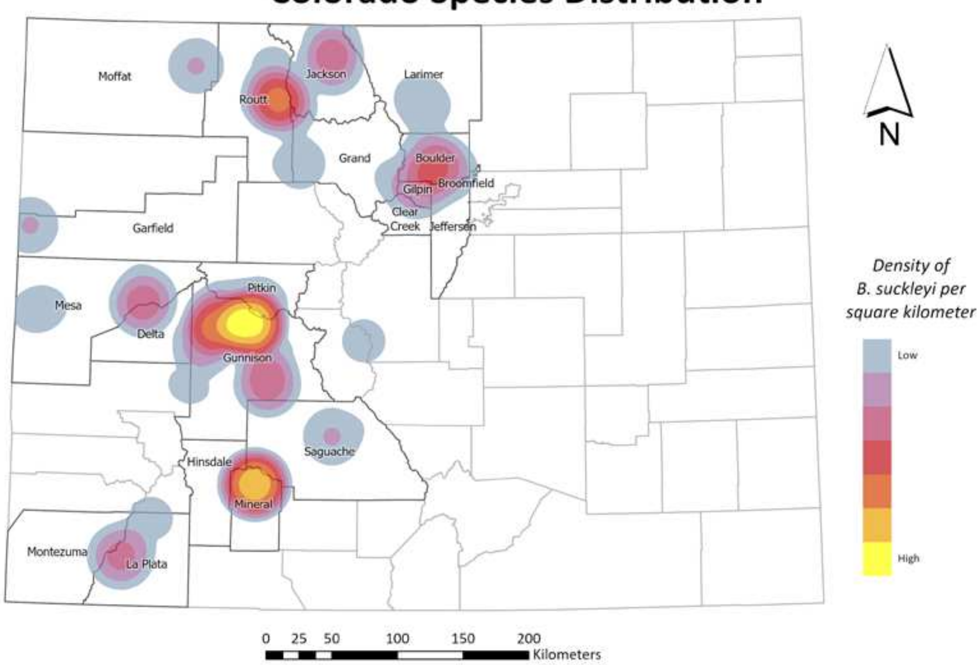
American Bumble Bee (*Bombus pensylvanicus)*
Colorado Species Distribution



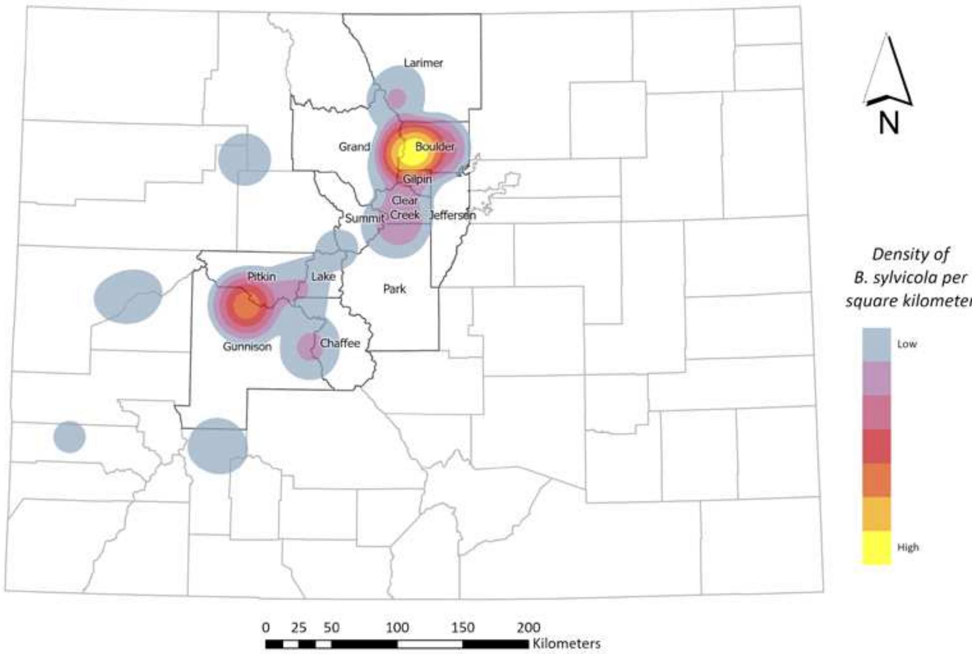
Red-belted Bumble Bee (*Bombus rufocinctus)*
Colorado Species Distribution



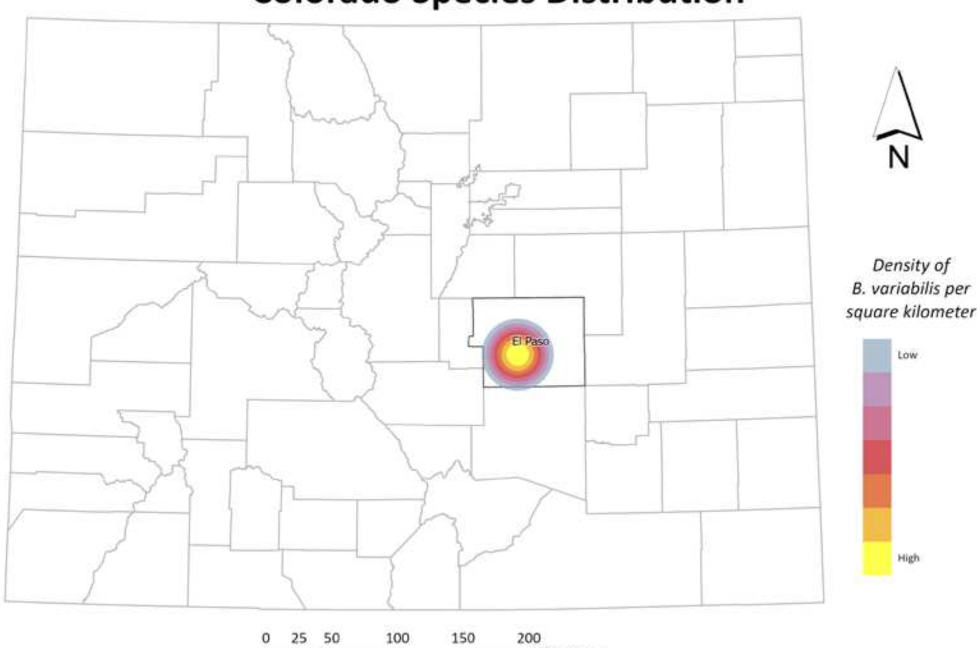
Suckley's Cuckoo Bumble Bee (*Bombus suckleyi)*
Colorado Species Distribution



Forest Bumble Bee (*Bombus sylvicola*)
Colorado Species Distribution



Variable Cuckoo Bumble Bee (*Bombus variabilis)*
Colorado Species Distribution



Appendix IV

Imperiled Pollinator Profiles

Two butterfly species found in Colorado are listed under the federal Endangered Species Act (ESA), another is proposed for listing as threatened, and a fourth is a candidate species as of March 2022. However, there are many imperiled pollinators in Colorado that are not protected by the ESA. This appendix provides profiles of ESA-listed, candidate, and proposed threatened pollinator species found in Colorado, as well as declining pollinators that have the potential to be listed in the future based on NatureServe rankings and expert opinion (Table IV). The profiles of imperiled species not listed under the ESA includes seven imperiled bumble bees and three imperiled butterflies. This is not an exhaustive list of all declining pollinators in Colorado. The profiles were developed by the Xerces Society for a series of regional roadside pollinator conservation guidebooks and are relevant for this study. Information about imperiled pollinators in Colorado is available in the State Wildlife Action Plan and from the Colorado Natural Heritage Foundation (CNHP) who tracks the status of at-risk species in Colorado.

This appendix presents information on life history, distribution, threats, and habitat requirements for the ten imperiled pollinators of focus. Information on known adult flight times (i.e., the breeding period) and larval active times (for butterflies; larval bees live within nests) are included. The profiles also include a list of important plants that are used by each species as host plants for larvae or as pollen and/or nectar sources for adults. Some of these plants are non-native species or noxious weeds. These species are included in the profiles, as the information may be useful, but using them in revegetation efforts is not recommended. Some basic conservation recommendations for each species are also provided if such information is available.

Table IV. List of profiled imperiled pollinator species in Colorado

SCIENTIFIC NAME	COMMON NAME	STATUS#
ESA-Listed Pollinator Species		
Boloria improba acrocnema	Uncompahgre fritillary	Endangered
Danaus plexippus	Monarch butterfly	Candidate
Hesperia leonardus montana	Pawnee montane skipper	Threatened
*Argynnnis nokomis nokomis** **(***Speyeria n. nokomis***)**	Great Basin silverspot butterfly	Proposed Threatened
Declining Pollinator Species		
Bombus fervidus	Yellow bumble bee	G3G4
Bombus fraternus	Southern plains bumble bee	G2G4
*Bombus pensylvanicus**	American bumble bee	G3G4
Bombus morrisoni	Morrison's bumble bee	G3
*Bombus occidentalis**	Western bumble bee	G3
*Bombus suckleyi**	Suckley's cuckoo bumble bee	G2G3
Bombus variabilis	Variable cuckoo bumble bee	G1G2
Atrytone arogos	Arogos skipper	G2G3
*Argynnis idalia** **(***Speyeria idalia***)**	Regal fritillary	G3?
Hesperia ottoe	Ottoe skipper	G3

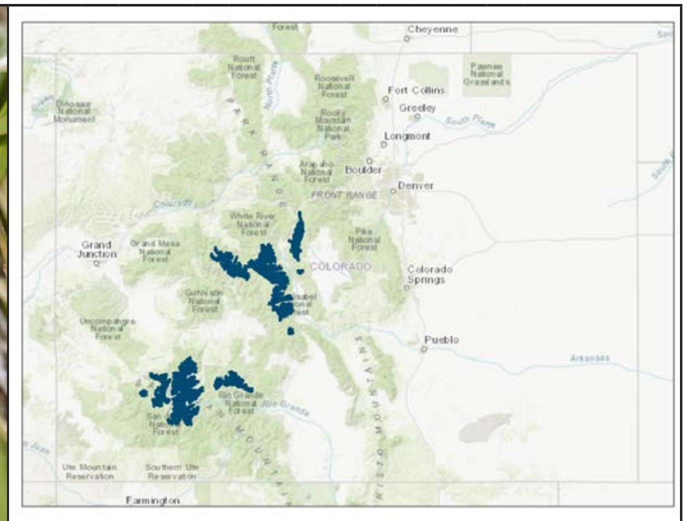
* Species under review or on the U.S. Fish and Wildlife Service workplan to be evaluated for listing under the ESA as of March 2022.

\# Status of pollinators is either the ESA status for listed species or is taken from NatureServe (accessed March 2022) for species not listed under the ESA.

- G1: Critically Imperiled. At very high risk of extinction due to extreme rarity (often five or fewer populations), very steep declines, or other factors.
- G2: Imperiled. At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.
- G3: Vulnerable. At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.
- G4: Apparently Secure. Uncommon but not rare; some cause for long-term concern due to declines or other factors.
- G5: Secure. Common; widespread and abundant.
- G#G#: Range Rank. A numeric range rank (e.g., G2G3) is used to indicate the range of uncertainty in the status of a species or community.
- T#: Infraspecific Taxon (for subspecies or varieties). The status of infraspecific taxa is indicated by a "T-rank" following the species' global rank. For example, the global rank of a critically imperiled subspecies of an otherwise widespread and common species would be G5T1.

ESA-Listed Pollinator Species

Uncompahgre Fritillary (*Boloria improba acrocnema*; formerly *Boloria acrocnema*)



Adult Uncompahgre fritillary (top left) and known distribution (top right). Adult flight times (i.e., breeding period; blue) and larvae active periods (green) are shown in the chart (bottom). See Life Cycle for more. Photo credit: Bill Bouton. Map Source: ecos.fws.gov, accessed March 2022.

Order: Lepidoptera
Family: Nymphalidae
Status: Endangered ; State status Critically Imperiled (S1), SWAP Tier 2
Distribution: Colorado
Where it occurs: High alpine habitat in the San Juan Mountains of Colorado, especially in Hinsdale County.
How to recognize: The Uncompahgre fritillary is a small butterfly with a wingspan of about 1 in.(25 mm). Upper sides of the wings are pale orange to a light rusty brown with black markings that can appear smeared. Wings of females are lighter than those of males. Undersides of the wings are light ocher. The underside of the hindwing has a bold band of white spots dividing the reddish-brown inner half from the purple-gray outer half.
Life cycle: Adult flight time occurs from late-June through early August. Adults fly at times when there is direct sunlight to aid in thermoregulation. Eggs are laid on or near snow willow (*Salix nivalis*), the larval host plant. This species' development may vary from 1 to 3 years, with most individuals developing in 2 years. Larvae make a shelter at the base of plants, underneath litter, before pupation.
Habitat needs: This species is mainly found in high alpine sites above 11,800 ft. (3,600 m) on northeast-facing slopes. It requires habitat with an abundance of snow willow and nectar sources.
Top reasons for decline, if known: Climate change, overcollection, trampling, and grazing.
Conservation recommendations: Protect remaining colonies of *B. acrocnema* and their habitat. Populations tend to be correlated with high diversity of flowering plants that can provide nectar, so management practices that conserve the host plant and a variety of nectar plants should be beneficial. Practices that mitigate climate change are also ultimately necessary to protect this species.

Plants Used by Uncompahgre Fritillary

LARVAL HOST PLANTS	
Species Name	**Common Name**
Salix nivalis	Snow willow[1]

1. Also used as a nectar plant

NECTAR PLANTS	
Species Name	**Common Name**
Erigeron vagus	Rambling fleabane
Erigeron simplex	Onestem fleabane
Silene acaulis ssp. *caulescens*	Moss campion
Phlox multiflora	Flowery phlox
Bistorta bistortoides	American bistort
Tetraneuris grandiflora	Graylocks four-nerve daisy
Geum rossii	Ross' avens
Minuartia obtusiloba	Twinflower sandwort

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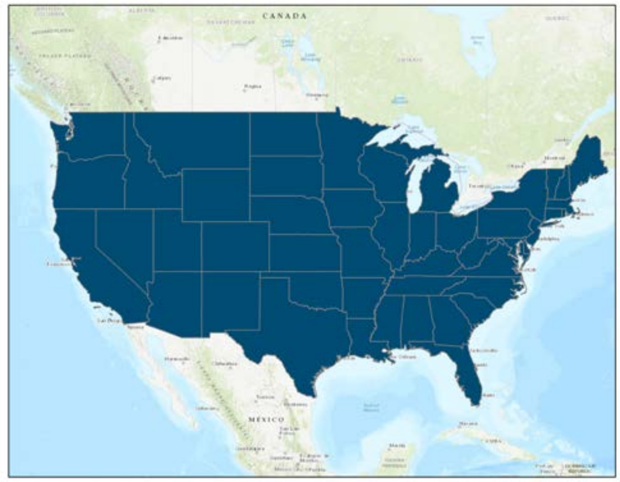
Seidl, A. L. 1996. Oviposition behavior and larval biology of the endangered Uncompahgre fritillary ***Boloria acrocnema*** (Nymphalidae). *Journal of the Lepidopterists' Society* 50:290–296.

U.S. Fish and Wildlife Service. 2009. Uncompahgre Fritillary Butterfly (***Boloria acrocnema***) 5 year review: summary and evaluation.

Monarch (*Danaus plexippus*)



	JAN–MAR	APRIL				MAY				JUNE				JULY				AUG				SEPT				OCT				NOV–DEC
Adult												X	X	X	X	X	X	X	X											
Larva										X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					

Adult monarch (top left) and monarch distribution within the U.S. (top right). Adult flight times (i.e., breeding period; blue) and larvae active periods (green) for monarchs in this region are shown in the chart (bottom). Adult and larval active times vary regionally and there is less information for this region than other parts of the U.S. Photo credit: Stephanie McKnight/The Xerces Society.

Order: Lepidoptera
Family: Nymphalidae
Status: Candidate; State status Secure (S5)
Distribution: As of 150 years ago, the monarch was restricted to southern Canada, the lower 48 states, Mexico, Central America and northwestern South America. In recent years the species has spread or been introduced to other areas, including Spain, Hawaii, Australia, and New Zealand.
Where it occurs: During the breeding season, monarchs can be found in terrestrial habitats throughout the western United States, but they tend to avoid dense forest.
How to recognize: Orange and black monarchs are larger than most butterflies with similar coloration. In contrast to the species that most closely resembles monarchs—the viceroy—monarchs lack the black line crossing the middle of each hind wing. Behaviorally, monarchs tend to glide more than most other butterfly species.
Life cycle: Western monarchs generally breed west of the Rocky Mountains and overwinter along the Pacific coast, while eastern monarchs generally breed east of the Rockies and overwinter in central Mexico. There is some mixing between the western and eastern populations, with some western monarchs migrating to central Mexico and vice versa. Monarchs have several generations a year, which spread out and move north and west from the overwintering sites. Less information is available about the phenology of monarchs in the Rocky Mountains. Breeding season in this region likely lasts from the spring through the fall. In the fall, adult monarchs enter reproductive diapause and return to overwintering sites. It is unknown if monarchs breeding in the Rocky Mountains generally overwinter in Mexico or along the Pacific coast. Individuals leave the overwintering grounds in the spring to lay eggs on milkweeds, the larval host plant. While larvae specialize on milkweed, adults use a variety of plants for nectar (see below).
Habitat needs: Although monarchs tend to avoid dense forests, they use most terrestrial and wetland ecosystems for breeding and migration, as long as those ecosystems have milkweeds and nectar sources. This includes roadsides: monarchs lay eggs on a variety of milkweed species on roadsides and in roadside ditches.
Top reasons for decline, if known: Loss and degradation of overwintering and breeding habitat; loss of habitat via conversion to row-crop agriculture and urban development; use of herbicides that kill milkweeds and nectar

sources; use of insecticides that kill monarchs or cause negative but sublethal effects.

General conservation recommendations: Protect and restore breeding habitat; this includes planting of native milkweed and nectar plants. Avoid planting the nonnative tropical milkweed, which leads to high concentrations of parasites. Finally, reduced use of pesticides will benefit the conservation of this species.

Plants Used by Monarch Butterfly

LARVAL HOST PLANTS	
Species Name	**Common Name**
Asclepias asperula	Spider milkweed
Asclepias incarnata	Swamp milkweed
Asclepias speciosa	Showy milkweed
Asclepias pumila	Plains milkweed
Asclepias subverticillata	Horsetail milkweed

NECTAR PLANTS	
Species Name	**Common Name**
Gaillardia aristata	Blanketflower
Helianthus annuus	Common sunflower
Liatris spp.	Blazing star
Solidago spp.	Goldenrod
Cleome serrulata	Rocky Mountain beeplant
Euthamia occidentalis	Western goldentop
Eriogonum umbellatum	Sulphur-flower buckwheat
Rudbeckia occidentalis	Western coneflower

Additional Information

- Native Milkweed Planting and Establishment in the Western United States
  xerces.org/publications/fact-sheets/native-milkweed-planting-and-establishment-in-western-united-states
- Monarch Nectar Plants: Rocky Mountains
  xerces.org/publications/plant-lists/monarch-nectar-plants-rocky-mountains
- Roadside Habitat For Monarchs: Milkweeds Of Colorado
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Pelton, E. M., C. B. Schultz, S. J. Jepsen, S. H. Black, and E. E. Crone. 2019. Western Monarch Population Plummets: Status, Probable Causes, and Recommended Conservation Actions. ***Frontiers in Ecology and Evolution*** 7:258.

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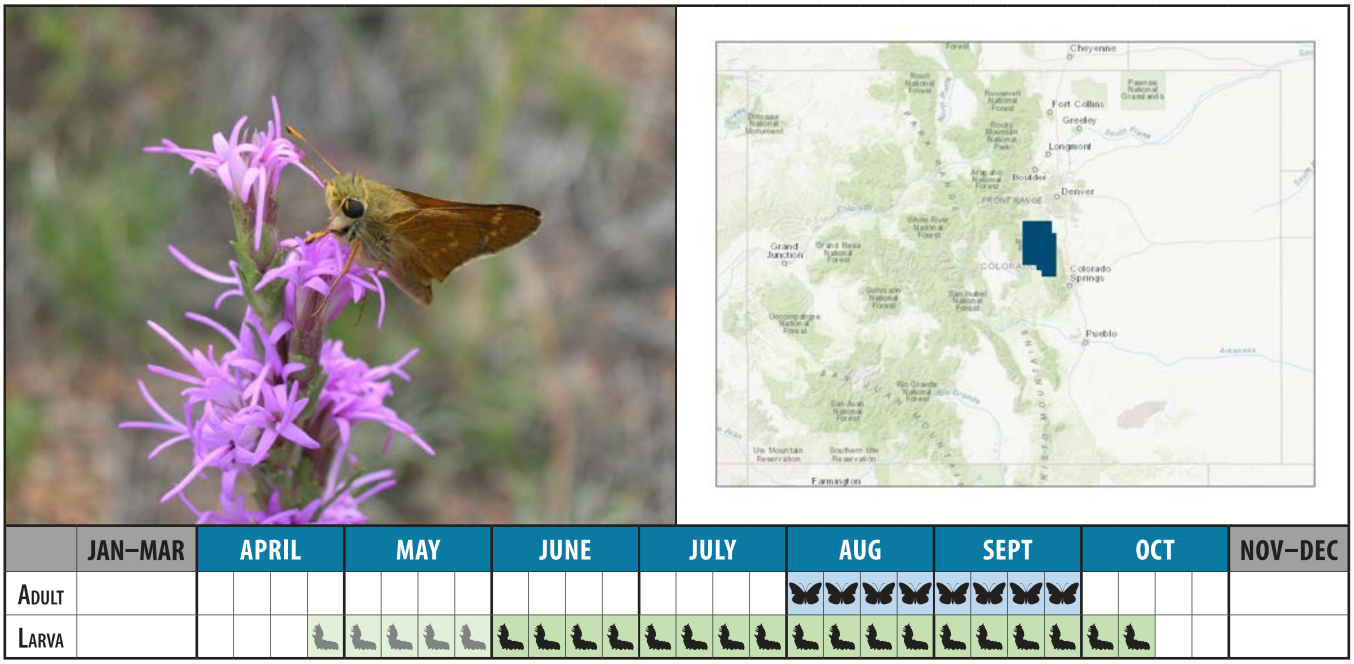
Pawnee Montane Skipper (*Hesperia leonardus montana*)



Adult Pawnee montane skipper (top left) and known distribution (top right). Adult flight times (i.e., breeding period; blue) and larvae active periods (green) are shown in the chart (bottom). Lighter shades indicate uncertain but likely active times. See Life Cycle for more. Photo credit: USDA & USFS. Map Source: ecos.fws.gov, accessed March 2022.

Order: Lepidoptera
Family: Hesperiidae
Status: Threatened; State status Critically Imperiled (S1), SWAP Tier 2
Distribution: Colorado
Where it occurs: This species is found along the South Platte River drainage system in four Colorado counties: Douglas, Jefferson, Park, and Teller. It is found in ponderosa pine/Douglas-fir woodlands. Much of this habitat occurs on Pike and San Isabel National Forest land.
How to recognize: A smallish butterfly with a wingspan of 1.25 to 1.75 in. (32 to 44 mm). Upper sides of the wings are mostly brown with orange bands. Undersides of the wings are yellowish-orange to brown with two to three (but occasionally one or four) faint or mostly absent whitish median spots.
Life cycle: Adult flight time occurs from August through September, when the prairie gayfeather (*Liatris punctata*), the primary nectar plant, is blooming. Eggs are laid singly on the host plant blue grama grass (*Bouteloua gracilis*). After hatching, early instar larvae hibernate over the winter, likely at the base of plants. There is still much to learn about the larval stages of this species.
Habitat needs: This species requires open habitat within the forested landscape. Long-term fire suppression has reduced the availability of open habitats where the required host and nectar plants grow. Fire suppression has also increased the risk of large-scale fires that remove the forest canopy, which can lead to long-term alteration of the habitat, making it unsuitable for these skippers. Characteristics of habitat where this species is known to occur include tree cover of 30 percent, tree density less than 200 per acre (500 per ha), shrub and grass cover less than 10 percent, stem densities of *L. punctata*, the most important nectar plant, between 50 and 500 stems per acre 125 and 1250 per ha), and 5 percent cover of the host plant *B. gracilis*, with uniform distribution.
Top reasons for decline, if known: Habitat loss and degradation, primarily through altered disturbance regimes (fire suppression) but also some development. Current threats include conditions associated with climate change, including increased temperatures, drought, and fire.
General conservation recommendations: Forest restoration projects that thin the forest to mimic historical conditions will create more openings that create conditions for blue grama grass and prairie gayfeather. Transects

conducted in such restoration plots have shown an increase in skipper numbers.

Plants Used by Pawnee Montane Skipper

LARVAL HOST PLANTS	
Species Name	**Common Name**
Bouteloua gracilis	Blue grama grass[1]

NECTAR PLANTS	
Species Name	**Common Name**
Liatris punctata	Prairie gayfeather[2]
Aster laevis	Smooth aster
Cirsium spp.	Thistles
Carduus nutans	Musk thistle[3]

1. Primary host plant
2. Primary nectar plant
3. Noxious weed

References

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Great Basin Silverspot (*Argynnis nokomis nokomis*, synonym: *Speyeria nokomis nokomis*)

	JAN–MAR	APRIL				MAY				JUNE				JULY				AUG				SEPT				OCT				NOV–DEC
Adult																X	X	X	X	X	X	X	X	X	X					
Larva						X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				

Adult Great Basin silverspot (top left) and known distribution (top right). Adult flight times (i.e., breeding period; blue) and larvae active periods (green) are shown in the chart (bottom). See Life Cycle for more. Photo credit: Robb Hannawacker. Map Source: ecos.fws.gov, accessed March 2022.

Order: Lepidoptera
Family: Nymphalidae
Status: Taxon vulnerable to critically imperiled (G3T1); Proposed Threatened under the ESA; State status Critically Imperiled (S1), SWAP Tier 2
Distribution: Arizona, Colorado, New Mexico, Utah
Where it occurs: This species range extends from eastern Utah (Unita and San Juan Counties) to western Colorado, and south to northern New Mexico and Arizona.
How to recognize: A medium-sized butterfly but larger than other similar-looking species, with a wingspan of 2.5 to 3 in. (63 to 76 mm). Undersides of the wings are orangish-brown with silvered spots and can look similar to those of other fritillary species, especially the great spangled fritillary *A. cybele*. The hindwing disc, which is essentially the inner half of the underside of the hindwing, is light brown in males and deep olive in females.
On the upper sides, males appear similar to other fritillary species that have orange wings with black markings. In females, upper sides of the wings are a dark bluish-black near the base of the wings; near the outside of the wings, the color lightens to white-cream or bluish-white.
Life cycle: Adult flight time is late-July through late-September. Eggs are laid singly near violet host plants and take 17 to 18 days to hatch. After hatching, first instar larvae enter diapause for the winter and emerge in the spring when violets are growing, around May. Larvae go through six instars and then pupate. The pupal stage takes about 17 days.
Habitat needs: This species is found in streamside meadows, seepage areas, and riparian areas along roadsides within arid deserts. These wet meadows may be interspersed with willows or other wetland woody plants. They require abundant larval host plants (bog violet) and nectar sources.
Top reasons for decline, if known: Habitat loss and habitat degradation, including altered hydrology, invasive species, livestock damage, and fire.
General conservation recommendations: Enhance habitat and protect from livestock and other forms of habitat

degradation. Increase habitat connectivity by seeding native species in riparian areas.

Plants Used by Great Basin Silverspot

LARVAL HOST PLANTS	
Species Name	**Common Name**
Viola nephrophylla	Bog violet[1]

NECTAR PLANTS	
Species Name	**Common Name**
Cirsium spp.	Thistles[2]
Carduus spp.	
Onopordon spp.	
Eupatorium maculatum	Joe Pye weed
Agastache spp.	Horsemint

1. Requires shade and soggy soil
2. This species favors native and nonnative thistles. Listed genera include native and nonnative species; some of the nonnative species are invasive.

References

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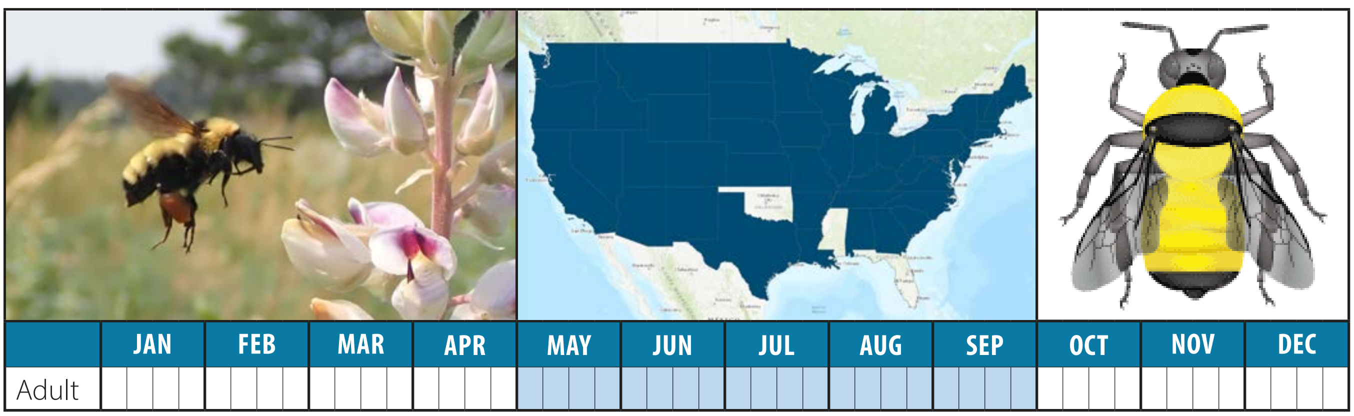
Declining Pollinator Species

Bumble Bees: General Notes for All Profiled Species

Order: Hymenoptera
Family: Apidae
Habitat Needs: Availability of food and nesting resources are key features in determining the success of a bumble bee colony. It is critical to maintain a bloom of floral resources throughout the spring, summer, and fall to supply bumble bees with a diversity and abundance of pollen and nectar, which is the food source for adults and larvae. Bumble bees nest above, on, or under the ground, utilizing pre-existing insulated cavities such as rock piles, areas of dense vegetation (e.g., bunch grasses), or old bird nests or mouse burrows. See table on page XXX for a list of plants used by bumble bees.
Top reasons for decline, if known: There are multiple factors affecting bumble bee decline including habitat loss, pesticide exposure, climate change, pathogens, and parasites, as well as the introduction of non-native bee species.
General conservation recommendations: Preserve, restore, and create high-quality habitat that includes suitable nesting, foraging, and overwintering sites throughout a species' range. Assess and mitigate risk of pesticide use in or near suitable habitat to avoid treating flowers in bloom or contaminating nesting and overwintering sites. Avoid the introduction of managed honey bees and managed bumble bees to areas of natural habitat to protect and minimize disease exposure.

Yellow Bumble Bee (*Bombus fervidus*)

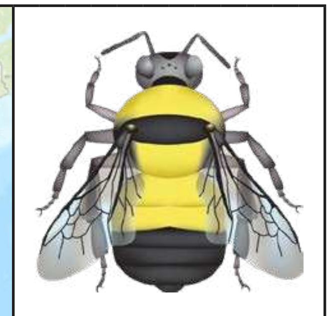


Adult yellow bumble bee (top left) and known U.S. state-level distribution (top right). Adult flight times (i.e., breeding period) are shown in the chart (bottom). Photo credit: Katie Lamke/The Xerces Society.

Status: Vulnerable to apparently secure (G3G4); no state status rank
Distribution: Widespread across the United States, except for the south-central and southeastern states
Where it occurs: Grassland, urban, forest, shrubland
Flight time: This species is typically active on the landscape from May through September. Between late-October and April, queens are overwintering in the ground.
Nesting behavior: Nests on the surface or aboveground; occasionally nests underground.
How to recognize: This bumble bee has black hair on the face; a yellow thorax with a narrow, black band between the wings; and a predominantly yellow abdomen with a black posterior end. Males may have different color patterns.
Body size: Medium. Queens range from 0.72 to 0.84 in. (18 to 21 mm) and workers range from 0.42 to 0.67 in. (11 to 17 mm).

Southern Plains Bumble Bee (*Bombus fraternus*)



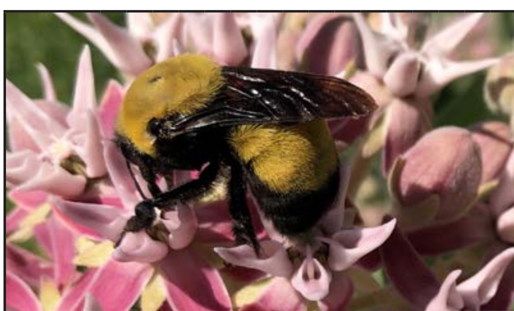


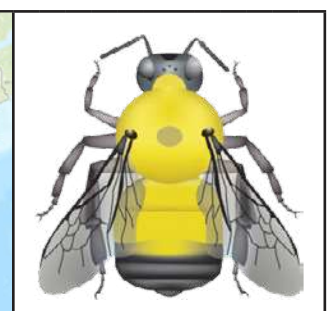
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Adult	□□□□	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	■■■■	□□□□	□□□□

Adult Southern Plains bumble bee (top left) and known U.S. state-level distribution (top right). Adult flight times (i.e., breeding period) are shown in the chart (bottom). Photo credit: Katie Lamke/The Xerces Society.

Status: Imperiled to apparently secure (G2G4); International Union for Conservation of Nature Red List: Endangered; State status Imperiled to Threatened (S2S3), SWAP Tier 2
Distribution: Central Great Plains to southeastern United States
Where it occurs: Grassland, urban
Flight time: This is an early emerging species, with queens becoming active on the landscape in May and June. This species will remain on the landscape through October. Between November and March, queens are overwintering in the ground.
Nesting behavior: Nests underground.
How to recognize: This bumble bee has black hair on the face and a predominantly yellow thorax with a narrow black oval between the wings. The first two segments of the abdomen are yellow and segments three through six are black, with hair lying flat. Males may have different color patterns.
Body size: Large. Queens range from 0.97 to 1.07 in. (25 to 27 mm) and workers range from 0.56 to 0.75 in. (15 to 19 mm).

Morrison's Bumble Bee (*Bombus morrisoni*)





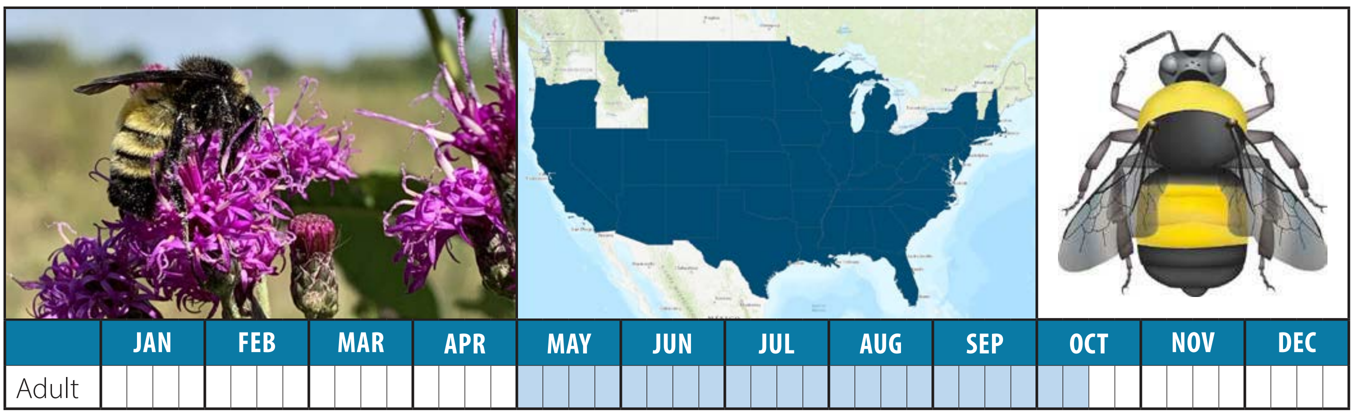
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Adult	□□□□	□□□□	□□□□	□□□□	■■■■	■■■■	■■■■	■■■■	■■■■	■■□□	□□□□	□□□□

Adult Morrison's bumble bee (top left) and known U.S. state-level distribution (top right). Adult flight times (i.e., breeding period) are shown in the chart (bottom). Photo credit: Leif Richardson/The Xerces Society.

Status: Vulnerable (G3); State status Imperiled to Apparently secure (S2S4), SWAP Tier 2

Distribution: Mountain and desert West
Where it occurs: Dry shrubland
Flight time: This species is typically active on the landscape from early May through mid-October. Between November and April, queens are overwintering in the ground.
Nesting behavior: Nests underground.
How to recognize: This bumble bee has black hair on the front of the face and yellow hair on the top of the head. The thorax is predominantly yellow, and black on the side. On the abdomen, segments one and two are yellow, segment three has some yellow, and segments four to six are black. Males may have different color patterns.
Body size: Large. Queens range from 0.87 to 1.02 in. (22 to 26 mm) and workers range from 0.47 to 0.87 in. (12 to 22 mm).

American Bumble Bee (*Bombus pensylvanicus*)

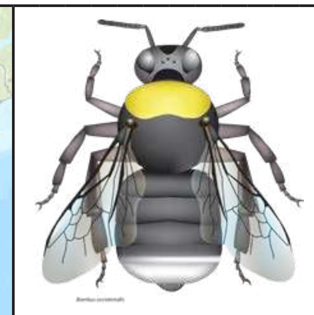
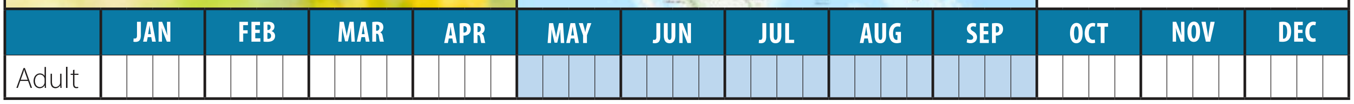


Adult American bumble bee (top left) and known state-level distribution (top right). Adult flight times (i.e., breeding period) are shown in the chart (bottom). Photo credit: Ray Moranz/The Xerces Society.

Status: This species has been petitioned for listing under the ESA. Vulnerable to apparently secure (G3G4); State status Imperiled to Vulnerable (S2S3), SWAP Tier 2
Distribution: Widespread in the United States; absent in much of the mountain West.
Where it occurs: Grassland, urban
Flight time: This species is typically active on the landscape late-March through October. Between late-November and early March, queens are overwintering in the ground.
Nesting behavior: Nests mostly on the surface among long grass; occasionally nests underground.
How to recognize: This bumble bee has black hair on the face. The thorax has a yellow band in front of the wings, with a black band between the wings; the band behind the wings may be black or yellow. The abdomen's anterior half is yellow, the posterior half is black (the first segment is sometimes black or half black). Note that males may have different color patterns.
Body size: Large. Queens range from 0.87 to 1.01 in. (22 to 26 mm) and workers range from 0.52 to 0.76 in. (13 to 19 mm).

Western Bumble Bee (*Bombus occidentalis*)



Adult western bumble bee (top left) and known U.S. state-level distribution (top right). Adult flight times (i.e., breeding period) are shown in the chart (bottom). Photo credit: Rich Hatfield.

Status: Vulnerable (G3), under review; petitioned in 2018 to be listed as endangered under the California Endangered Species Act; petitioned in 2015 to be listed as endangered or threatened under the ESA; State status Vulnerable to Apparently secure (S3S4), SWAP Tier 2

Distribution: Western United States from the coast to mountain meadows out to northwestern Great Plains. Population has shown sharp decline since the late 1990s west of the Sierra Nevada and Cascade Range.

Where it occurs: Urban, shrubland, grassland

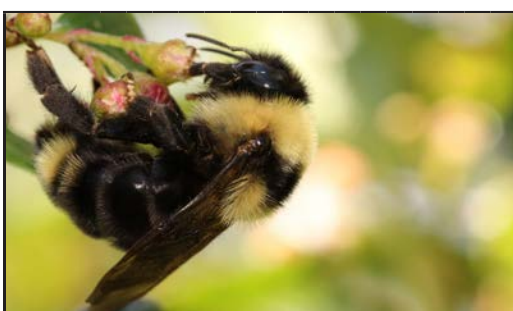
Flight time: This species is typically active on the landscape from May through September. Between October and April, queens are overwintering in the ground.

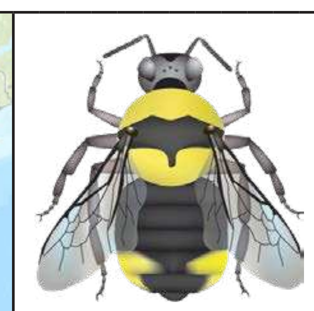
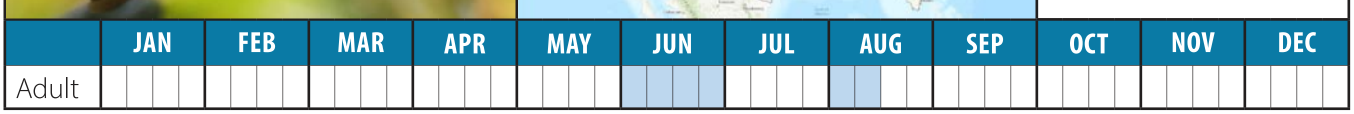
Nesting behavior: Usually nests underground.

How to recognize: This bumble bee has mixed black and yellow hair on the face. The thorax has a yellow band in front of the wings and a black band or spot between the wings; behind the wings can be black, yellow, or mixed. Segment one of the abdomen is black, segments two and three are black or have some yellow, segments four and five are white or pale yellow, and segment six is black. Males may have different color patterns.

Body size: Medium. Queens range from 0.77 to 0.84 in. (20 to 21 mm) and workers range from 0.36 to 0.59 in. (9 to 15 mm).

Suckley's Cuckoo Bumble Bee (*Bombus suckleyi*)

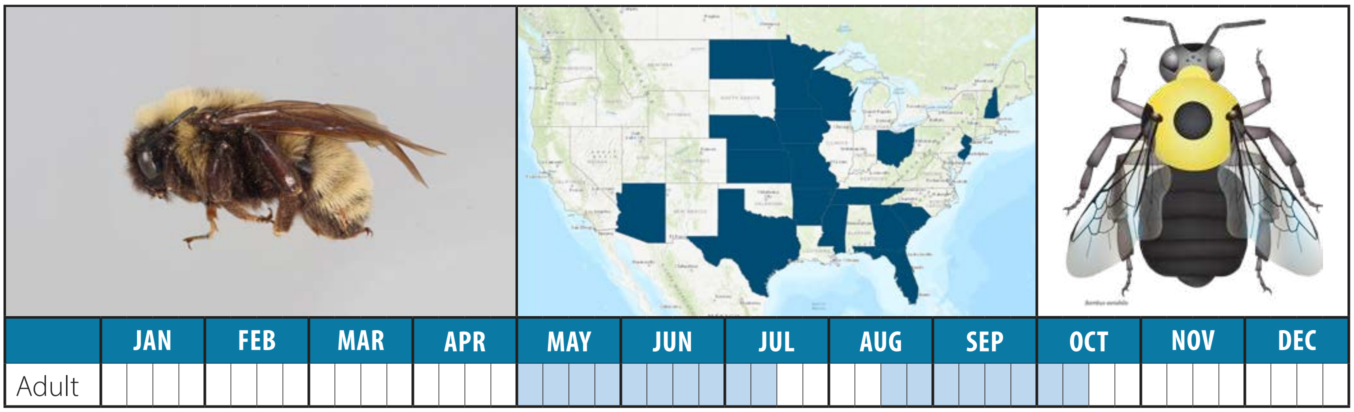


Adult Suckley's cuckoo bumble bee (top left) and known U.S. state-level distribution (top right). Adult flight times (i.e., breeding period) are shown in the chart (bottom). Photo credit: Cory Sheffield.

Status: Imperiled to vulnerable (G2G3); under review for listing under the ESA; State status Imperiled (S2), SWAP Tier 2
Distribution: Mountain West and north into Canada
Where it occurs: Forest, grassland, shrubland
Parasite of: Western bumble bee (*B. occidentalis*)
Flight times: This species is typically active on the landscape in June and again in early to mid-August. During the peak of summer, this species remains in the host's nest.
Nesting behavior: Parasite of western bumble bee, which nests underground.
How to recognize: This bumble bee has black hair on the face and a predominantly yellow thorax with a black stripe between the wings. The abdomen is predominantly black with a yellow band toward the posterior end interrupted medially. Males may have different color patterns.
Body size: Medium. Females range from 0.72 to 0.92 in. (18 to 23 mm).

Variable Cuckoo Bumble Bee (*Bombus variabilis*)



Adult variable cuckoo bumble bee (top left) and known state-level distribution (top right). Adult flight times (i.e., breeding period) are shown in the chart (bottom). Photo credit: Laurence Packer/www.DiscoverLife.org.

Status: Critically imperiled to imperiled (G1G2); State status Possibly extirpated (SH)
Distribution: Midwest of the United States, occurring in the Great Plains and temperate forest areas. Scattered along the coast of the southeastern United States. This species has always been uncommon.
Where it occurs: Urban, grassland, forest
Parasite of: American bumble bee (*B. pensylvanicus*)
Flight times: This species is typically active on the landscape between May and mid-July, then again from late August through mid-October. During the peak of summer, this species remains in the host's nest.
Nesting behavior: Parasite of the American bumble bee (*B. pensylvanicus*), which usually nests on the surface among long grass; occasionally nests underground.
How to recognize: This bumble bee has black hair on the front of the face; the top of the head is yellow. The thorax has a yellow band in front of the wings; the area between the wings may be all yellow, or it may have a black band or a black spot. The area behind wings may have a yellow band or intermixed black hairs. The abdomen is black, unless it is a male, which may display varying degrees of yellow on any segment. Note that males may have different color patterns.
Body size: Medium. Females range from 0.73 to 0.87 in. (18 to 22 mm).

Plants Used by Bumble Bees

SPECIES NAME	COMMON NAME	NOTES
Early		
Balsamorhiza sagittata	Arrowleaf balsamroot	Yellow; perennial
Penstemon grandiflorus	Large-flowered Beardtongue	White/purple; perennial
Rosa nutkana	Nootka rose	Pink; perennial
Tradescantia occidentalis	Western spiderwort	Blue/purple; perennial
Mid		
Cleome serrulata	Rocky mountain beeplant	Purple; annual
Dalea purpurea	Purple prairie clover	Purple; perennial
Lupinus argenteus	Silvery lupine	Purple; perennial
Monarda fistulosa	Bee balm/wild bergamot	Purple; perennial
Late		
Agastache urticifolia	Nettle leaf horsemint	White/pink; perennial
Liatris punctata	Dotted blazing star	Purple; perennial
Rudbeckia laciniata	Cutleaf coneflower	Yellow; perennial
Symphyotrichum novae-angliae	New England aster	Purple; perennial

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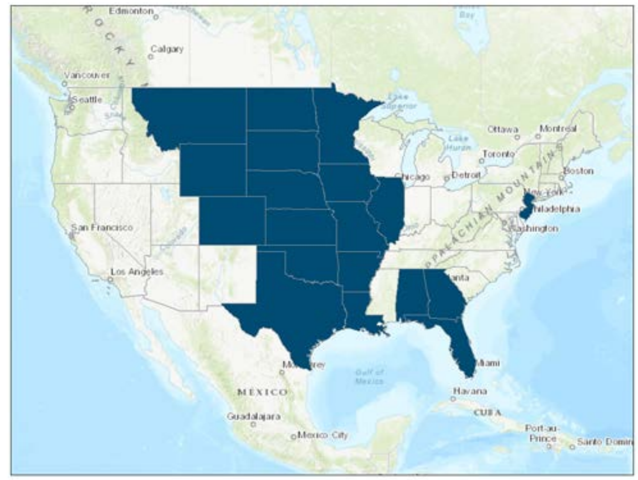
Arogos Skipper (*Atrytone arogos*)



Adult arogos skipper (top left) and known state-level distribution (top right). Adult flight times (i.e., breeding period; blue) and larvae active periods (green) for this region are shown in the chart (bottom). Lighter shades indicate uncertain but likely active times (see Life Cycle for more). Photo credit: Mike Zapata_Bugwood.org.

Order: Lepidoptera

Family: Hesperiidae

Status: Imperiled to vulnerable (G2G3); State status Imperiled (S2), SWAP Tier 2. The arogos skipper has suffered massive declines in abundance since the 1800s and seems to be extirpated or very sparse throughout its range except for Oklahoma, where this species has been reported in dozens of counties since the year 2000. It is also locally abundant in the Front Range of Colorado.

Where it occurs: This species occurs in undisturbed prairies and grasslands, including both shortgrass and tallgrass prairies. In the Front Range, it is found in moist meadows in foothill canyons and ridges.

How to recognize: Skippers tend to be small butterflies. Their ventral surfaces are yellow-orange, and the wing veins are often paler than the wing membranes. The fringe (a band of long, narrow scales at the outside edges of the wings) is often white. Males and females both have broad, dark margins on the ventral surfaces of the wings. Suspected sightings should be verified through photographs sent to experts. It may be most easily confused with the more common Delaware skipper (*Anatrytone logan*).

Life cycle: Adult flight times vary regionally for this species. In Colorado this species has one brood per year, with adults flying from June to July. Fourth-stage caterpillars hibernate, complete their feeding the next spring, and then pupate in a leaf cocoon in vegetation about 3 feet above the ground.

Habitat needs: Remnant savannas and native grasslands, including shortgrass and tallgrass prairie. Big bluestem (*Andropogon gerardii*) and little bluestem (*Schizachyrium scoparium*) appear to be the main host plants for larvae of this species in Minnesota. The presence of nectar sources is important, as is an appropriate amount of disturbance. This species can be extirpated from sites by frequent mowing, especially if grasses are not allowed to seed, and through wildfires or prescribed burns, and seems to do poorly with fire return intervals of 2 years or less.

Top reasons for decline, if known: Unclear, but likely loss of high-quality remnant grasslands and pine savannas along with inappropriate fire regimes. Populations have been extirpated by prescribed fires as well as wildfires.

General conservation recommendations: Protect remnant grasslands from conversion to other land uses. Restore native grasslands and savannas where possible. Manage habitat with fire or mowing, but infrequently (once every 3 years at the most) to keep this species from being extirpated by fire or mowing.

Plants Used by the Arogos Skipper

LARVAL HOST PLANTS	
Species Name	**Common Name**
Andropogon gerardii	Big bluestem
Schizachyrium scoparium	Little bluestem

NECTAR PLANTS	
Species Name	**Common Name**
Asclepias spp.	Milkweeds
Centaurea spp.	Knapweeds[1]
Cirsium spp.	Thistles
Echinacea angustifolia	Narrowleaf coneflower
Liatris spp.	Blazingstars

1. Noxious weed

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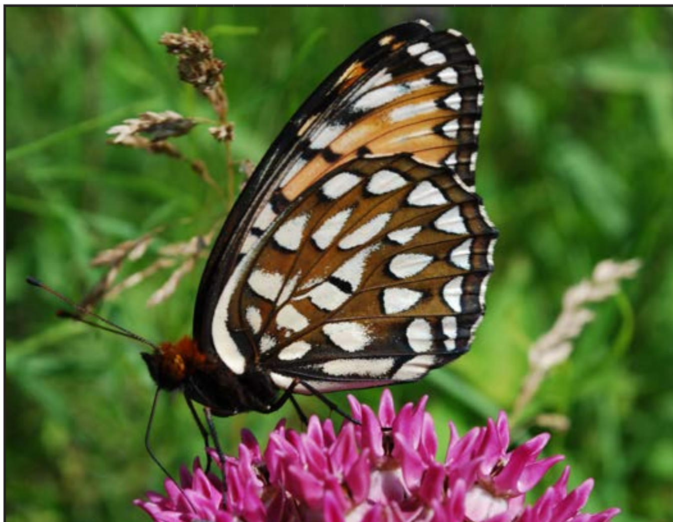
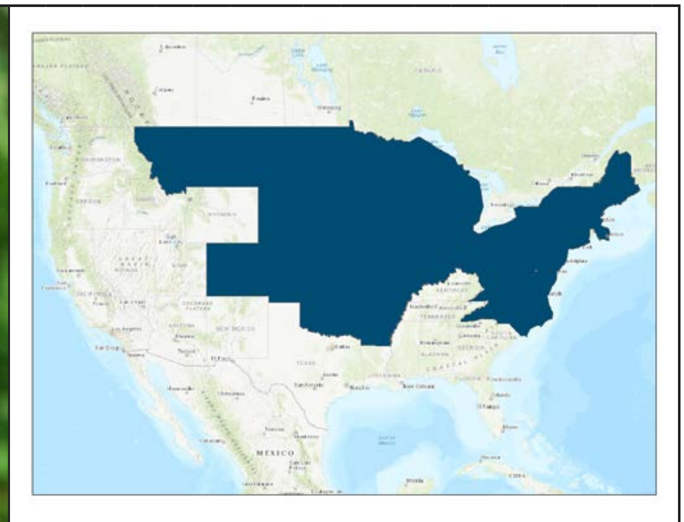
Regal Fritillary (*Argynnis idalia*, synonym: *Speyeria idalia*)





	DEC–MAR	APRIL				MAY				JUNE				JULY				AUG				SEPT				OCT				NOV			
ADULT												🦋	🦋	🦋	🦋	🦋	🦋	🦋	🦋	🦋	🦋	🦋	🦋	🦋	🦋	🦋	🦋	🦋	🦋				
LARVA		🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛	🐛			

Adult regal fritillary (top left) and known state-level distribution (top right). Adult flight times (i.e., breeding period; blue) and larvae active periods (green) for this region are shown in the chart (bottom). See Life Cycle for more. Photo credit: Ray Moranz. Map Source: ecos.fws.gov, accessed March 2022.

Order: Lepidoptera

Family: Nymphalidae

Status: Vulnerable (G3?); petitioned for listing under the ESA; State status Critically imperiled (S1), Swap Tier 2

Distribution: Historically, from Northern Plains (including Manitoba) to Maine and from Oklahoma to North Carolina. It is thought to have been extirpated from 15 states, primarily in the east. It is known to still occur in Arkansas, Colorado, Iowa, Illinois, Indiana, Kansas, Minnesota, Missouri, North Dakota, Nebraska, Oklahoma, Pennsylvania, South Dakota, Wisconsin, and Wyoming.

Where it occurs: Mainly in prairies in the Central Grasslands, but also in grasslands at Fort Indiantown Gap in Pennsylvania and at the Radford Army Ammunition Plant in Virginia. Eastern Colorado is the southwestern range-limit for this species.

How to recognize: Large butterfly with bold, distinctive color patterns that flies with a rapid wing beat. Upper sides of the forewings are orange; upper sides of the hindwings are dark purple with rows of orange and white spots (male) or white spots only (female). Undersides of the forewings are orange with black spots, while undersides of hindwings have large, bright white spots contrasting with a hazy copper background.

Life cycle: This species is univoltine, producing a single generation per year. Adult flight time occurs from mid- to late-June through October. In the Northern Plains, adult males emerge from chrysalids from mid- to late-June, with females emerging 2 weeks later. They mate, and most males are dead by late-July. After mating, females are relatively inactive in July and August, each one laying thousands of eggs, one at a time, near grassland violets (their host plants) in September and October. Larvae burrow under the litter to hibernate for the winter soon after hatching. Around April, larvae become active and begin feeding on violets until pupation.

Habitat needs: Grasslands with violets and high-quality nectar sources (e.g., *Asclepias*, *Echinacea*, *Liatris*, *Monarda*, *Verbena*). Minimum habitat patch size is unknown, but 20 acres (8 ha) is likely too small to maintain a local population over the long term. Disturbance (i.e., fire, mowing) is often needed to counter woody plant encroachment, but fire or mowing should be conducted on one-third or less of the site each year to minimize the chance of extirpating the population.

Top reasons for decline, if known: Habitat loss (conversion of habitat to row-crop agriculture, improved pasture, and urban/suburban development); encroachment of woody plants and invasive exotics that reduce habitat quality.

General conservation recommendations: Restore habitat by restoring diverse, native prairie with violets and nectar sources. Manage habitat with fire, haying, or mowing to maintain native forb populations and prevent woody plant encroachment. Avoid use of insecticides and broadcast spraying of broad-spectrum herbicides in and near habitat. Persistence of this species will likely depend on having large, connected habitat available throughout its range. Work to increase availability of violets for use in restoration efforts.

Plants Used by the Regal Fritillary

LARVAL HOST PLANTS	
Species Name	**Common Name**
Viola bicolor	Field pansy
Viola pedata	Birdfoot violet
Viola pedatifida	Prairie violet
Viola sororia	Common blue violet
Viola spp.	Violets

NECTAR PLANTS	
Species Name	**Common Name**
Asclepias speciosa	Showy milkweed
Asclepias sullivantii	Prairie milkweed
Asclepias syriaca	Common milkweed
Asclepias tuberosa	Butterfly milkweed
Asclepias verticillata	Whorled milkweed
Cephalanthus occidentalis	Buttonbush
Cirsium spp.	Thistles
Echinacea angustifolia	Narrow-leaved coneflower
Heliopsis helianthoides	Smooth oxeye
Liatris pycnostachya	Prairie blazing star
Monarda fistulosa	Wild bergamot
Verbena stricta	Hoary vervain
Vernonia baldwinii	Baldwin's ironweed

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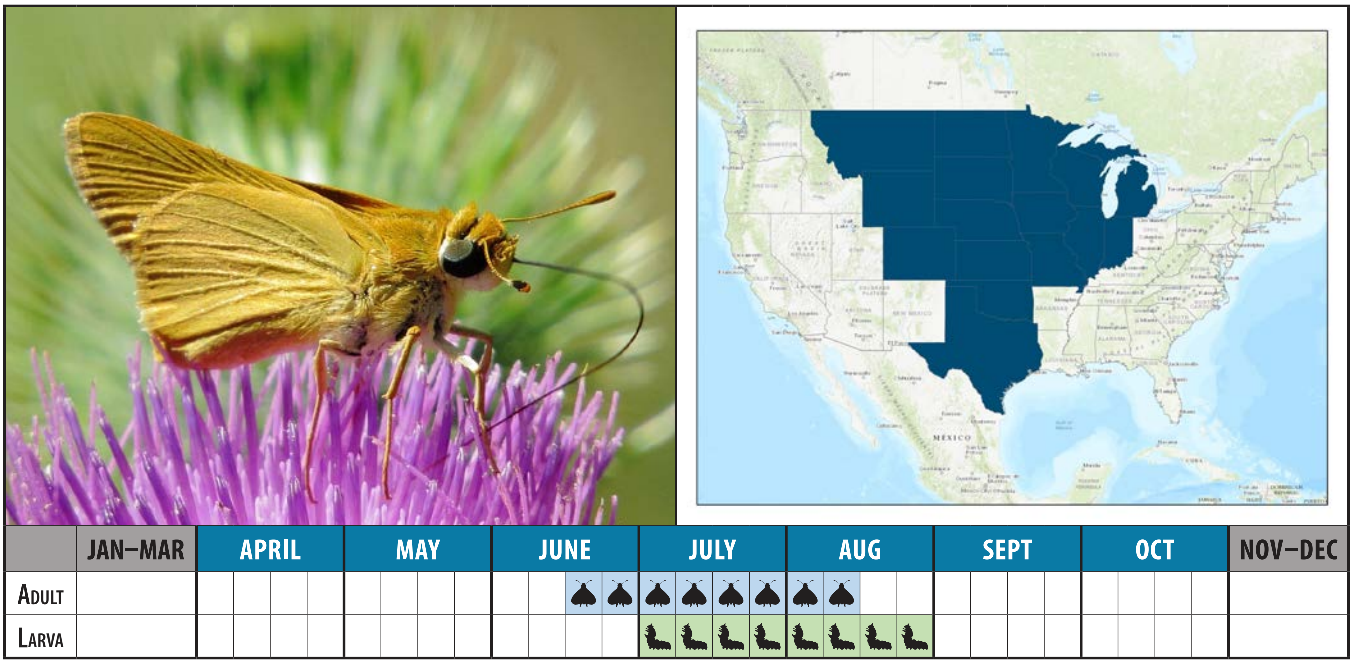
Ottoe Skipper (*Hesperia ottoe*)



Adult Ottoe skipper (top left) and known state-level distribution (top right). Adult flight times (i.e., breeding period; blue) and larvae active periods (green) are shown in the chart (bottom). The larvae are in aboveground shelters during the "active" time (see Life Cycle for more). Photo credit: Bill Carrell / iNaturalist.

Order: Lepidoptera

Family: Hesperiidae

Status: Vulnerable (G3), given that it rarely occurs away from high-quality prairie and continues to decline in abundance; State status Imperiled (S2), SWAP Tier 2.

Distribution: Colorado, Iowa, Illinois, Indiana, Kansas, Michigan, Minnesota, Missouri, Montana, North Dakota, Nebraska, Oklahoma, South Dakota, Texas, Wisconsin, and Wyoming, as well as southern Manitoba. This species may be extirpated from Minnesota.

Where it occurs: This species occurs in high-quality grassland habitat, including mid-grass and tallgrass prairies in the Great Plains and dry prairies and barrens in the Great Lakes regions. Along the Colorado Front Range, it is found in stands of big bluestem (*Andropogon gerardii*).

How to recognize: One of the larger grass skippers, it is pale yellow underneath but has more striking coloration on the upper surfaces, with males having wide brown borders to the forewings and females having wide brown borders and a glassy spot in the middle of the forewing.

Life cycle: A single brood per year, with adults flying between late June and early August. Eggs are laid singly on grasses such as little bluestem (*Schizachyrium scoparium*) and big bluestem (*A. gerardii*), and occasionally on forbs such as coneflowers (*Echinacea* spp.). Larvae construct above ground shelters from grasses, where they feed through late summer during the first three instars. They overwinter as larvae in new subterranean shelters constructed at the base of grasses. In the spring, they construct shelters from silk and other debris on the soil surface, where they complete feeding and then pupate.

Habitat needs: Requires prairie with native prairie grasses and an abundance of native nectar-producing forbs such as coneflowers (*Echinacea* spp.) and milkweeds (*Asclepias* spp.).

Top reasons for decline, if known: Habitat loss, including conversion of rangeland to row-crop agriculture; inadequate rangeland management (inappropriate grazing, mowing, and fire regimes).

General conservation recommendations: Conserve large expanses of native rangeland. Manage rangeland to ensure an abundance of nectar sources and prevent tree encroachment. How to manage rangeland properly with regard to this species is poorly understood, so managing heterogeneously seems to be very important (i.e., avoid large-scale burning or mowing that might harm an entire population). Maintain abundant nectar sources.

Plants Used by the Ottoe Skipper

LARVAL HOST PLANTS	
Species Name	**Common Name**
Andropogon gerardii	Big bluestem
Schizachyrium scoparium	Little bluestem
Schizachyrium scoparium	Little bluestem
Bouteloua gracilis	Blue grama
Bouteloua curtipendula	Sideoats grama
Bouteloua hirsuta	Hairy grama
Bromus spp.	Bromes[1]
Carex geyeri	Geyer's sedge[2]
Digitaria cognata	Fall witchgrass
Panicum wilcoxianum	Fall rosette grass
Sporobolus neglectus	Puffsheath dropseed

NECTAR PLANTS	
Species Name	**Common Name**
Liatris spp.	Blazing stars
Asclepias syriaca	Common milkweed
Asclepias viridiflora	Green comet milkweed
Silphium laciniatum	Compass plant
Echinacea angustifolia	Narrow-leaved coneflower
Verbena stricta	Hoary verbena
Cirsium flodmanii	Flodman's thistle

1. This genus includes native and nonnative species; some of the nonnative species are invasive
2. Western edge of Northern Plains

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Appendix V

Information Available Upon Request

The survey administered to state staff and federal staff that participated in this study is available by contacting CSU Extension or the Xerces Society.


Photo: Adrian Carper

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Colorado Native Pollinating Insects Health Study

Inquiries about this study should be directed to the
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